SYSTEM-FRIENDLY COMPETITIVE RENEWABLE ENERGY PROCUREMENT IN BANGLADESH

SCALING UP RENEWABLE ENERGY (SURE)

OCTOBER 2020

SYSTEM-FRIENDLY COMPETITIVE RENEWABLE ENERGY PROCUREMENT IN BANGLADESH

SCALING UP RENEWABLE ENERGY (SURE)

OCTOBER 2020

Prepared for:
Energy and Infrastructure Office
U.S. Agency for International Development
1300 Pennsylvania Ave NW, Washington DC 20523

Prepared by:
Tetra Tech ES, Inc.
1320 North Courthouse Road, Suite 600
Arlington, VA 22201
www.tetratech.com

USAID TASK ORDER AID-OAA-I-13-00019AID-OAA-TO-17-00011

Acknowledgements

This white paper was prepared by Tetra Tech ES, Inc., and Guidehouse (subcontractor). Contributors included Fabian Wigand, Ana Amazo, Bastian Lotz and Tobias Fichter from Guidehouse; and Ritesh Kumar Singh, Dr. Alam Hossain Mondal and Abu Bakar Siddiq from Tetra Tech. This white paper is one of the outcomes of USAID's Scaling Up Renewable Energy (SURE) project in Bangladesh. We sincerely thank USAID/Bangladesh, which put forth the idea of writing this white paper, with special thanks to Mr. Shayan Shafi, Senior Energy Advisor, USAID/Bangladesh. His help and contributions are highly appreciated.

The publication of this white paper would not have been possible without contributions from power sector stakeholders, who generously provided their time and input during the consultation process. We want to thank: Md. Faruque Ahmed, Project Director, Bangladesh Power Development Board (BPDB); Md. Rifat Hossain, Assistant Engineer, BPDB; Sk. Munir Ahmed, Director (Management), Power Cell; Md. Shahnewaz Islam, Executive Engineer, BPDB; Mrs. Jorifa Abrar, Deputy Director, BPDB; Mr. S.M. Zahid Hasan, Deputy Director, BPDB; Md. Muzibur Rahman, Superintending Engineer, Dhaka Power Distribution Company (DPDC); Mr. Quazi Ashiqur Rahman, Executive Engineer, DPDC; Mr. Abdullah Al Mamun, Head of Project Development Team, Teesta Solar Limited; Mr. Habibur Rahman Faisal, Project Construction Head, Teesta Solar Limited; Mr. Chakma Chandan, Project Engineer, Teesta Solar Limited; Mr. Ahmed Muntasib Chowdhury, Senior Manager, Engreen Limited; Engr. Mukit Alam Khan, Manager, US-DK Green Energy (BD) Limited; Engr. Md. Monwar Hasan Khan, Senior Advisor, GIZ Bangladesh; and Mr. M. F. Shadekul Islam Talukder, National Expert, GFA Consulting Group GmbH.

We would also like to thank the reviewers from the U.S. National Renewable Energy Laboratory (NREL), who provided valuable feedback to this white paper, particularly Barbara O'Neill (Manager, Grid Integration), Mark Jacobson (Senior Project Leader, Integrated Applications Center) and Carishma Gokhale-Welch (Technical Project Lead).

Contents

Figures & Tables

List of Acronyms

BERC	Bangladesh Energy Regulatory Commission
BEZA	Bangladesh Economic Zone Authority
BPDB	Bangladesh Power Development Board
CfD	Contract for Difference
CHP	Combined Heat and Power
COVID-19	Coronavirus Disease 2019
CUF	Capacity Utilization Factor
DPDC	Dhaka Power Distribution Company Limited
DSM	Demand-Side Management
EGCB	Electricity Generation Company of Bangladesh
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GoB	Government of Bangladesh
HVDC	High Voltage Direct Current
IDCOL	Infrastructure Development Company Limited
IPP	Independent Power Producer
KOREM	Kazakhstan Energy and Power Market Operator
LNG	Liquified Natural Gas
NLDC	National Load Dispatch Center
NREL	National Renewable Energy Laboratory
NTPC	National Thermal Power Corporation
PGCB	Power Grid Company of Bangladesh
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
SECI	Solar Energy Corporation of India
SREDA	Sustainable and Renewable Energy Development Authority
VPP	Virtual Power Plant
VRE	Variable Renewable Energy

List of Unit Measurements

BDT	Bangladesh Taka
GHI	Global Horizontal Irradiance
GW	Gigawatt
GWh	Gigawatt-hour
Hz	Hertz
INR	Indian Rupee
km	Kilometer
kV	Kilovolt
kWh	Kilowatt-hour
kWh/m^2	Kilowatt-hour per Square Meter
kWp	Kilowatt-peak
m/s	Meter per second
m^2	Square Meter
MW	Megawatt
MWh	Megawatt-hour
MWh/MW	Megawatt-hour per Megawatt
USD ($)	United States Dollar
W/m^2	Watt per Square Meter

Executive Summary

Increasing the share of variable renewable energy (VRE) in its power system would allow Bangladesh to diversify its power mix and reduce the risks associated with volatile prices of fossil fuels, as well as the negative environmental impacts of thermal power generation. At the same time, Bangladesh faces several challenges to the reliable operation of its power system, such as VRE projects' remote location from the grid and road infrastructure, limited land availability for project development, and issues with frequency stabilization in case of imbalances between power demand and supply. Before the COVID-19 pandemic, forecasts pointed to growing peak demand in Bangladesh that would increase the need for dispatchable renewable energy (RE) that can reliably deliver electricity during peak periods. While the COVID-19 pandemic and its resulting lockdowns and economic effects have reduced overall demand and changed demand patterns worldwide, there remains uncertainty about how long these changes will last. The pandemic further strengthens the need for system-friendly procurement of renewable energy to increase system resilience and flexibility, reduce system costs for utilities and end-consumers, and provide Bangladesh with energy sources that are less exposed to volatility in global fuel prices.

System-friendly competitive procurement represents an **opportunity for Bangladesh to address the system challenges** of increasing VRE capacity early and facilitate the continued integration of VRE into its power system. System challenges include the temporal mismatch between VRE generation and demand (its timing), the intermittency of VRE generation (its quality), and the physical distance between VRE generation and demand centers (its location). These inherent characteristics of VRE can affect the power system's supply adequacy, the requirement for balancing services, and the need for grid infrastructure upgrades or extensions.

The **temporal mismatch** between daily peak demand and peak supply in Bangladesh (especially during the summer months) has led to regular load shedding. Annual electricity demand and peak loads can be expected to increase further due to economic and population growth. The intermittency of VRE generation increases the need for system flexibility in the form of reserve and residual load-following requirements to balance supply and demand. Bangladesh's power system faces challenges in managing frequency control, in part due to the absence of adequate frequency control measures.

The **spatial mismatch** between demand centers and locations where electricity from utility-scale VRE projects is injected into the grid might become an issue. The current plans for grid expansion consider conventional capacity additions, but generally do not plan for the integration of RE projects, which are often located far from the national grid (particularly solar and wind projects).[1] Bangladesh might require grid infrastructure upgrades or extension in the southern and southeastern coastal areas, where future RE project development is expected to be centered.

Policymakers can use **design solutions for system-friendly RE procurement**, including time-based incentives, location-based incentives, physical hybrids, and virtual hybrids (supply-side aggregators). Table 1 provides a summary of these design solutions, including the international experiences analyzed in this white paper.

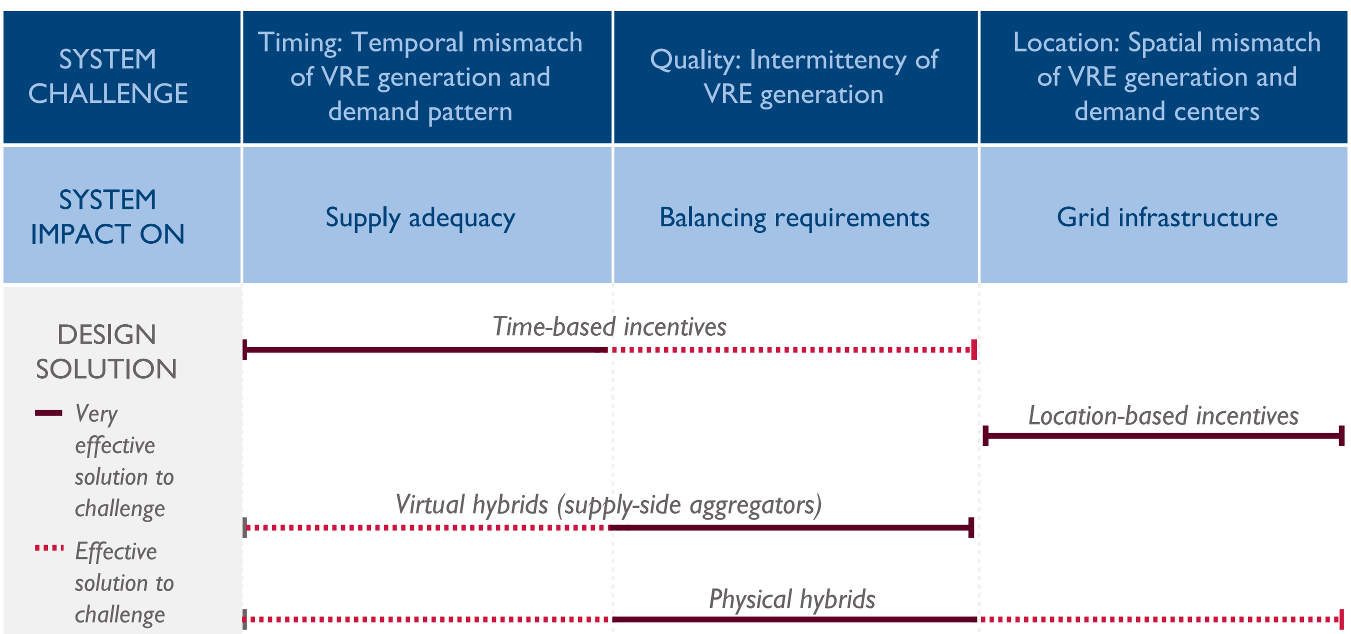
This paper draws from desktop research, primary information gathered through a written consultation with power sector stakeholders in Bangladesh in June 2020, and a preliminary data analysis of the complementarity of solar and wind resources in the Chattogram area. While stakeholder comments and suggestions were of great value to this paper, the positions presented in the paper do not necessarily constitute their opinions.

1 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.

TABLE 1: Overview of Design Solutions for Innovative RE System-Friendly Procurement

DESIGN SOLUTION	DESCRIPTION	BEST PRACTICE EXAMPLE
Time-based incentives	Time-based incentives support RE generation that more closely matches the power demand curve.	**Chile's** intraday and seasonal supply blocks
Location-based incentives	Location-based incentives steer the location of projects to specific areas and grid connection points to avoid the concentration of projects in areas that are resource-rich but costly to connect.	**Kazakhstan's** capacity quotas
Physical hybrids	Physical hybrids combine technologies such as wind and solar installations (and potentially storage) to offset the technology-specific intermittencies of VRE and allow for more efficient use of land and transmission capacity.	**India's** hybrid tenders
Virtual hybrids (supply-side aggregators)	Virtual hybrids, or aggregators, bundle different power system units at different grid connection points (e.g., dispatchable and non-dispatchable RE, demand response resources, storage); units are dispatched via virtual control systems.	Next Kraftwerke's virtual power plant in **Germany**

FIGURE 1: Overview of System Integration Challenges of VRE and Suitability of Design Solutions



The various design solutions differ in terms of their suitability to address Bangladesh's system challenges, which result from the timing, location, and quality of VRE electricity injected into the grid, as well as their feasibility of implementation. Figure 1 presents an overview of system challenges, resulting system impacts, and suitable design solutions.

Suitability of design solutions to Bangladesh: Time-based incentives can be particularly suitable to increase VRE's contribution to supply adequacy, while carefully planned site-specific auctions (location-based incentives) can mitigate the pressure on grid infrastructure expansion requirements. Virtual and physical hybrids tap into the system benefits resulting from the combination of VRE technologies, such as complementary feed-in patterns and, in the case of virtual hybrids, spatial smoothing effects over larger geographical areas to provide more firm power, reducing the need for balancing requirements.

Feasibility of design solutions for Bangladesh: Site-specific auctions, a type of location-based incentive implemented in Bangladesh, could benefit considerably from adequate project site selection and pre-development by the government. This could prevent issues such as the selection of sites that are difficult to reach for construction and service, as in the 2019 wind auction.[2] Time-based incentives can be a viable option in Bangladesh if the state-owned utility and other relevant authorities provide and regularly update information on power system characteristics such as current and projected load patterns and include these in their procurement processes. Solar-wind physical hybrid auctions could be implemented but require the identification of sites with good wind and solar resources and land availability. Virtual hybrids are currently not feasible in Bangladesh due to the absence of a wholesale power market or a market for corporate power purchase agreements (PPA) and a lack of compensation for the supply of firm power and ancillary services. Table 2 summarizes the applicability of innovative design solutions for system-friendly RE procurement to Bangladesh.

The white paper concludes with recommendations and brief action items for procuring institutions and other relevant power sector stakeholders in Bangladesh.

Recommendation 1: Continuously improve site selection and pre-development of site-specific auctions to address grid and land constraints (location-based incentives). Adequate site selection and pre-development of sites by the government could help address problems finding sites with available grid capacity and land (the location challenge of VRE). The selection and pre-development of project sites can be performed by procuring agencies such as the Bangladesh Power Development Board (BPDB) and its generation companies in coordination with the Sustainable and Renewable Energy Development Authority (SREDA) and the Power Grid Company of Bangladesh (PGCB).

Recommendation 2: Consider tender documents such as tariff adjustments or supply blocks to promote a more dispatchable supply (time-based incentives). Including tariff adjustments, supply blocks or obligations for specific times of the day and/or year in Bangladesh's competitive VRE procurement could incentivize the supply of power during peak demand to support supply adequacy (the timing challenge of VRE), and to some extent reduce the balancing requirements from conventional generators (the quality challenge of VRE). Data required to calculate tariff adjustments or supply blocks include current and expected future hourly load in the transmission grid, as well as current and expected availability of generation capacity and its expected daily and seasonal generation patterns. The tender documents can be developed by RE procuring agencies such as BPDB, in coordination with SREDA and PGCB. Moreover, the Government of Bangladesh (GoB) should facilitate the development of guidelines for procurement agencies and the National Load Dispatch Center (NLDC) on how to define peak and off-peak periods, tariff adjustments for time-of-delivery, or penalties for supply shortages if supply blocks are implemented.

Recommendation 3: Explore the potential to auction solar-wind hybrids. Before announcing the auctioning of solar-wind hybrid capacities, procuring entities should identify sites where good wind and solar resources overlap (e.g., in Bangladesh's south and southeastern coastal regions), based on wind speed and solar irradiation data such as the U.S. National Renewable Energy Laboratory's (NREL) geospatial tool for wind or the World Bank's Solargis for solar. Because the estimated energy yield of wind projects depends on site-specific conditions, potential wind sites should be selected first based on more

2 BPDB 2019b. In September 2020, BPDB announced the re-tendering of two 50 MW projects to be built in Chandpur and Inani (Cox's Bazar). The two project sites are part of the government's initiative to build 150 MW of grid-connected wind power capacities in Mongla, Inani (Cox's Bazar) and Chandpur. The project near Mongla is in the award process under the first wind power tender (May 7, 2019) for one of three sites with 50 MW projects.

TABLE 2: Summary of the Suitability and Applicability of Design Solutions for System-Friendly RE Procurement in Bangladesh

	TIME-BASED INCENTIVES	LOCATION-BASED INCENTIVES	PHYSICAL HYBRIDS	VIRTUAL HYBRIDS (SUPPLY-SIDE AGGREGATORS)
SUITABILITY				
Timing challenge of VRE	Incentivize the supply of power during peak demand to support supply adequacy		Extend the period during which supply can be guaranteed compared to single-technology wind or solar PV plants, and (partially) support supply adequacy	Enable the shifting of VRE power to peak demand periods to increase supply adequacy
Quality challenge of VRE	(Partially) reduce the residual load		Reduce the intermittency of generation compared to single-technology wind or solar PV plants	Provide firm electric power to reduce the need for balancing requirements
Location challenge of VRE		Reduce the pressure on grid expansion and upgrade	Maximize grid use (MWh/MW) by co-locating solar with wind capacities	
FEASIBILITY				
	Requires information on current and projected load patterns to define peak and off-peak periods	Requires adequate project site selection and pre-development by the government in site-specific auctions	Requires identification of sites with both adequate wind and solar resources and land availability	Requires wholesale power market, market for corporate PPAs and/or compensation for firm power and ancillary services (currently absent in Bangladesh)

site-specific measurements. Once potential wind sites have been pre-selected, a resource assessment (solar and wind) for relevant sites should be performed. SREDA can develop guidance documents on how to adjust the design of site-specific auctions to procure physical hybrid capacities. Key elements for the design include the definition of a minimum capacity utilization factor and penalties for supply deviations, as well as adjusting the ceiling price and the project commissioning deadline.

Recommendation 4: Enhance power system flexibility beyond competitive procurement design to support the integration of VRE. This includes measures such as the expansion and reinforcement of the power grid, as well as the increased use of power imports and exports, demand-side management (DSM), and storage solutions. Decision-makers could define an integrated roadmap for a large-scale integration of RE into the energy system in concertation with stakeholders such as BPDB, SREDA, PGCB, and the Bangladesh Energy Regulatory Commission (BERC). In addition, Bangladesh should develop the skills and methods required to plan and operate a power system with high shares of VRE, such as how to forecast RE generation and calculate operating reserve requirements.

CHAPTER 1.

INTRODUCTION

1.1 Background

Competitive procurement for renewable energy had been implemented in more than 100 countries by the end of 2019.[3] Solar photovoltaic (PV) prices have dropped as low as 1.58 U.S. cents/kWh (1.34 BDT/kWh[4]) in Qatar,[5] 1.65 cents/kWh (1.40 BDT/kWh) in Portugal and 1.69 cents/kWh (1.44 BDT/kWh) in Dubai, and wind power prices have dropped as low as 1.86 cents/kWh (1.58 BDT/kWh) in Mexico.[6] However, as the share of renewable energy (RE) in power systems increases, system integration challenges and associated costs are growing.

System-friendly competitive procurement incentivizes the deployment of RE by maximizing its value to the system and considering that in the award decision. The concept of system value goes beyond the power generation costs of an awarded project; it refers to a generation technology's contribution to reducing relative system costs for electricity supply.

While the installed grid-connected RE capacity in Bangladesh stood at 318.96 MW[7] as of October 2020, grid capacity and stability concerns will become more pressing with an increased share of variable renewable energy (VRE). The location of several VRE projects far from the grid, as well as frequency control management issues, already pose challenges for reliable power system operation.[8] Furthermore, with the growing peak demand in Bangladesh (which increased from 6,454 MW in 2010 to 12,223 MW in September 2020[9]), the importance of dispatchable RE that delivers electricity during evening peaks and measures that steer power demand will increase.

1.2 Problem statement

This white paper analyzes the applicability of design solutions for system-friendly RE procurement to Bangladesh and provides recommendations on their implementation. The paper begins with an overview of the power sector in Bangladesh and highlights what its characteristics imply for VRE system integration. Next, it presents innovative design solutions for system-friendly RE procurement and international examples, followed by an assessment of the suitability and feasibility of these solutions for Bangladesh. The paper concludes with actionable recommendations for energy policy planners in Bangladesh to design a more system-friendly RE competitive procurement scheme.

This paper draws from desk research, primary information gathered through a written consultation with power sector stakeholders in Bangladesh in June 2020, as well as a preliminary data analysis of the complementarity of solar and wind resources in the Chattogram area. While stakeholder comments and suggestions were of great value to this paper, the positions presented in the paper do not necessarily constitute their opinions.

3 IRENA, *Renewable Energy Auctions Status and Trends Beyond Price*, 2019.
4 1 USD = 84.9314 BDT (Source: XE Currency Converter, July 2020)
5 Bellini, "Qatar's 800 NW tender draws world record solar power price."
6 IRENA, 2019.
7 Total RE installed capacity in Bangladesh is 649.61 MW, of which 330.62 MW consists of off-grid installations and 318.96 MW of on-grid installations (230 MW from hydro, roughly 38 MW from utility-scale solar PV and wind, and the remaining from rooftop solar PV). Source: SREDA, *National Database of Renewable Energy*, 2020.
8 Frequency control management or regulation is a service provided by both generation and demand sources to keep a balance between produced and consumed power and so maintain the system frequency at its nominal value of, for example, 50 Hz in Bangladesh. When supply exceeds demand, the frequency in the grid increases. When demand exceeds supply, the frequency in the grid decreases.
9 For the 2010 data: BPDB, *Annual Report* 2009-2010, 2010. For the 2020 data: BPDB website on September 19, 2020.

TABLE 3: List of Key Terms Used

TERM	DEFINITION
Competitive procurement	A competitive process for procuring electricity generated by RE.[10] It is designed to allocate a supply contract or incentive, based solely on the bids submitted by participating bidders according to transparent award rules.[11] The bid evaluation criteria can be based solely on price or include additional award criteria such as system integration, the creation of local industry, the environmental impacts of a project, or its local/social acceptability. The terms "tender" and "auction" are also used to designate this type of procurement process.
Variable renewable energy (VRE)	Electricity generation technologies whose primary energy source varies over time and cannot easily be stored. Variable generation sources include solar, wind, ocean, and some hydro generation technologies.[12]
Residual load	System load minus electricity generation from VRE (also called net load).
System integration of RE	This encompasses all the technical, institutional, policy, and market design changes needed to enable the secure and cost-effective uptake of large amounts of VRE in the energy system.[13] Examples include grid expansion and upgrades, system operating procedures and market practices, as well as power system planning.[14]
System integration cost	The cost imposed on the power system to integrate a resource. The concept highlights that generation costs of VRE do not reflect the full cost and value for the system.[15] The calculation of system integration costs is complex, and results depend on costs included, methodology applied, and where costs and benefits occur. System integration costs for VRE can be caused by necessary grid enforcement and expansion, more extensive cycling and ramping of conventional power plants to follow residual load, increased balancing procedures to offset the differences between forecasts for electricity generation by VRE and actual production, and the provision of firm back-up capacity.
System-friendly RE procurement	System-friendly competitive procurement incentivizes the deployment of RE by maximizing its value to the system and considering it in the award decision. System value refers to the contribution of a generation technology to reducing relative system costs for electricity supply.

1.3 Motivation of the white paper

Bangladesh defined a RE target of 2,470 MW by 2021 and 3,864 MW by 2041.[16] Integrating VRE would allow the country to diversify its power mix and reduce the risks associated with the volatile prices of fossil fuels, as well as the negative environmental impacts of thermal power generation. At the same time, generators using VRE resources for electricity supply (such as wind and solar) have intermittent output, and the best RE sources are often located far from urban demand centers. The large-scale deployment of VRE introduces challenges to maintaining adequate frequency and voltage levels at all timescales, from sub-seconds to years, that power system planners and operators must consider. In a country with a relatively low share of RE power like Bangladesh, system-friendly competitive procurement represents an opportunity to facilitate the greater integration of RE.

10 IRENA, 2015.
11 AURES, 2015.
12 Greening the Grid, *glossary*.
13 IEA, 2018.
14 NREL, n.d.
15 Palchak et al., 2017.
16 Targets for renewable energy generation capacity are set out in the 2016 Power Sector Master Plan (PSMP): 2,470 MW by 2021 and 3,864 MW by 2041. Source: Government of Bangladesh, Power System Master Plan (*PSMP*) 2016, 2016.

First, system-friendly competitive procurement can **reduce the temporal mismatch** between VRE generation and electricity demand. The generation of VRE is weather-dependent and has variable seasonal and intraday patterns. VRE generators without storage or non-hybridized with dispatchable generators can be considered as non-dispatchable generation technologies. Hence, VRE electricity is delivered when it is abundant instead of when it is most needed during peak load periods.

This affects supply adequacy, the ability of a power system to reliably meet electricity demand during all hours of the year. Procuring more dispatchable, low-cost RE to meet demand, even during peak times, can help address this challenge. Options include setting incentives (such as higher tariffs or supply blocks following load patterns) or procuring electricity from hybrids or aggregators that include dispatchable RE installations or storage.

Second, system-friendly competitive procurement can **reduce the spatial mismatch** between where electricity is fed into the grid (at the best RE resource sites) and where it is needed (demand centers). In many cases, the best RE resources are located far from demand centers to minimize generation costs. Scaling up RE often requires grid expansion and enforcement to access high-quality solar and wind resources. In addition, a geographic concentration of RE deployment may cause congestion in the transmission grid, leading to increased RE curtailment rates. At the same time, grid development can be expensive and requires a well-planned, multi-year process. Competitive procurement with price or quantity signals that steer RE development to locations with enough grid capacity or the preselection of applicable sites by the government can mitigate the need for grid expansion.

Last, system-friendly competitive procurement can **reduce the intermittency of VRE generation.** System operators have always had to manage load variability through prudent operating reserves practices. However, the intermittent resource availability of VRE increases the variability of supply and that of the residual load that needs to be supplied by dispatchable power plants. Although VRE generation can be forecasted, some uncertainty in forecasts remains. This uncertainty can, however, be reduced with the roll-out of state-of-the-art forecasting tools and improved communications between grid regions.

VRE system integration goes beyond competitive procurement design: it spans a variety of measures including grid expansion and upgrades, system operation procedures and market practices, and power system planning.

These system challenges affect the power system's balancing requirements—day-ahead forecasting errors and short-term variability of RE output cause intraday adjustments, requiring the operation of a flexible residual system and reserve capacities that can respond within seconds to minutes. By procuring firm generation capacity via virtual hybrids (supply-side aggregators) or physical hybrids, countries can reduce the need for balancing in the system.

Countries increasingly adopt design solutions to address VRE system integration challenges, such as time-based and location-based incentives, virtual hybrids, and physical hybrids (see section 3). However, VRE system integration goes beyond competitive procurement design: it spans a variety of measures including grid expansion and upgrades, system operation procedures and market practices, and power system planning.[17] As countries plan to increase the share of VRE, power systems will need to become more flexible. Flexibility options relate to electricity transmission between regions, demand-side integration, dispatchable generation, and energy storage as well as effective ancillary services and shorter-term frequency responsive reserves.

17 Greening the Grid, *Overview of Grid Integration Issues.*

CHAPTER 2.

OVERVIEW OF THE POWER SECTOR IN BANGLADESH

The following section provides an overview of the power sector in Bangladesh, including power supply and demand (section 2.1), renewable energy deployment (section 2.2), the transmission grid system (section 2.3), and system operation (section 2.4). It also summarizes the implications for RE integration in Bangladesh. Unless otherwise stated, all information in this section is based on the BPDB Annual Report 2018-2019.

2.1 Power supply and demand

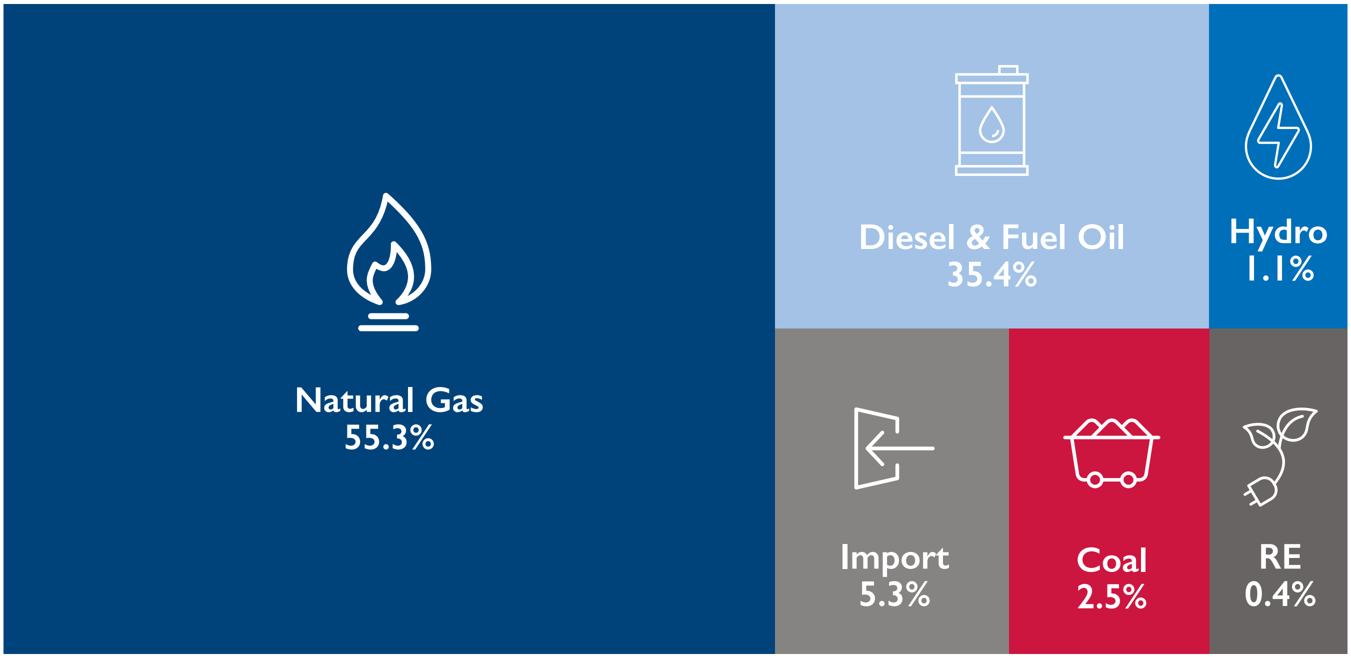
According to the Bangladesh Power Development Board (BPDB), as of October 15, 2020 Bangladesh had 20,813 MW of grid-connected, installed generation capacity, with natural gas representing the largest share at 55.3 percent of installed capacity (11,502 MW), followed by diesel and furnace oil with 35.4 percent (7,362 MW), coal with 2.5 percent (524 MW), and hydropower with 1.1 percent (230 MW).[18] Solar PV power capacities stood at roughly 89 MW, of which approximately 38 MW are represented by utility-scale installations, while wind power capacities stood at 0.9 MW, according to the Sustainable and Renewable Energy Development Authority (SREDA).[19] Figure 2 provides an overview of Bangladesh's generation capacity mix in 2020.

Before the COVID-19 pandemic, Bangladesh's demand for power was growing by about 10 percent per year, and this rate was expected to increase as a result of economic growth (annual real GDP growth was 7.9 percent in 2018[20]). Originally, it was expected that 1,500 MW would be needed every year for the next 20 years to meet projected demand.[21] In fiscal year 2018–2019, Bangladesh generated 70,533 GWh of energy, which was 12.5 percent higher than the previous year.

The COVID-19 pandemic and its resulting lockdowns and economic effects have, however, affected the power system, power demand patterns and power demand forecasts worldwide—with continuing uncertainty about how long these impacts will last. First analyses by the International Energy Agency on the impact of COVID-19 show that electricity demand has fallen by 20 percent or more during periods of full pandemic-related lockdown in several countries.[22] These effects are due to a supply shock, where economic activity is partly constrained to prevent the spread of the virus, and a demand shock, where a loss of income reduces consumer spending and corporate investments. While residential demand has increased, the reduction in commercial and industrial demand is severe, changing the demand patterns of weekdays to resemble more the weekend pattern. As the uncertainty around future COVID-19 developments remains, so does uncertainty around developments in power demand. In April

18 BPDB, *Generation Report*, October 2020, https://www.bpdb.gov.bd/bpdb_new/index.php/site/daily_generation.
19 SREDA, *National Database of Renewable Energy*.
20 World Bank Open Data.
21 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.
22 IEA, Global Energy Review 2020.

FIGURE 2: Bangladesh's Generation Capacity Mix[23]



Source: BPDB 2020, SREDA 2020

2020, the IMF forecasted 2 percent GDP growth for 2020, a major driver of power demand; in September, it increased the prediction to 3.8 percent and for 2021 to 4.4 percent.[24] Assumptions about the pandemic and GDP growth will also be a major driver in the current redrafting of Bangladesh's Power System Master Plan. There also remains pandemic-induced uncertainty about the system site as field work on major transmission infrastructure projects was suspended.[25] Irrespective of actual developments in demand, the need for system-friendly procurement of renewable energy remains—to increase system flexibility, reduce system costs for utilities and end-consumers, and provide Bangladesh with energy sources that are less exposed to global fuel price developments.

As of September 2020, peak demand occurs between 5:00 p.m. and 11:00 p.m. reaching 12,223 MW, while the maximum peak generation is 12,892 MW (see Table 4). After several years where power demand outpaced supply, the supply of power in Bangladesh currently lies above the demand.

However, there is a considerable gap between the total installed capacity and the maximum peak generation, which can be explained by gas shortages, derated power plant capacity due to aging, and plant unavailability due to maintenance or overhauling.[26] In addition, challenges in maintaining reliable spinning reserves[27] for frequency regulation and a distribution grid in need of upgrades have resulted in load shedding in order to adjust demand to available generation and stabilize frequency, particularly during peak hours in summer months.

Most stakeholders consulted for this paper agree that, particularly in urban areas, the currently observed trend toward higher evening demand peaks is likely to continue in the future. However, some note that policymakers' renewed focus on demand-side management (DSM) and the country's economic transition and industrialization (e.g., the establishment of economic zones) may shift demand to the day and thus reduce evening peaks.

23 The figure combines data from BPDB as of October 2020 for total on-grid installed capacities and from SREDA as of September 2020 for RE capacities. Power imports are calculated as the difference between the total installed capacity and the sum of the other energy sources. At the time of publication, this information was not yet consolidated in an annual report by BPDB.
24 Ovi, I.H., *IMF: Bangladesh to overtake India in per capita GDP*.
25 Hasan, *COVID-19 fallout: Power transmission projects work to be delayed by a year*.
26 BPDB, *Annual Report 2017-2018*.
27 Spinning reserves are reserves that are online and connected to the system. Spinning reserves are traditionally held to address power plant failures and random variation in demand. Source: NREL, *Wind and solar on the power grid: Myths and misperceptions*, 2015.

TABLE 4: Key Statistics of Bangladesh's Power Sector[28]

	2018–2019	2020 (SEPTEMBER)
Total installed capacity	18,961 MW	20,813 MW
Maximum peak generation	12,893 MW	12,892 MW
Maximum peak demand	PSMP forecast 13,044 MW Actual 11,500 MW	PSMP forecast 14,757 MW Actual 12,223 MW
Capacity utilization during peak hours	68.0 percent	Not yet available
Total generation	70,533 GWh	Not yet available[29]
Per-unit generation cost	5.95 BDT/kWh (7 cents/kWh)[30]	Not yet available

To meet the additional projected demand, the Government of Bangladesh (GoB) plans to add significant amounts of new generation capacity: 37,509 MW between 2019 and 2030.[31] In June 2019, 50 power plants with a total capacity of 15,151 MW were under construction.[32] Additions include new coal- and gas-fired power plants as well as solar PV and wind power capacities.

Bangladesh is also shifting toward greater imports of power, coal, and liquified natural gas (LNG), primarily from India. While the domestic gas sector previously supplied all the gas used by power plants, production from domestic onshore gas fields is steadily declining,[33] with discoveries failing to meet the growth in gas demand and existing gas reserves approaching depletion.[34] Power imports started in 2013 with 500 MW and have now increased to 1,160 MW.

2.2 Renewable energy

Increasing the amount of electricity generated from RE can help Bangladesh meet the projected increase in power demand, mitigate the reduction in indigenous natural gas resources, and improve energy security by reducing dependence on imported coal and LNG.[35] In its Power System Master Plan 2016, Bangladesh defined a target of 2,470 MW of RE capacity by 2021 and 3,864 MW by 2041. According to the same plan, solar PV and wind power will be the key focus areas for future capacity additions, given that Bangladesh has already exhausted its hydro resources. Moreover, the country is planning to trade power with Nepal and Bhutan to access their hydro resources using the Indian transmission grid.[36] The plan estimates the hydropower import potential from Nepal and northwest India to be in the range of 2.5 to 8.5 GW by 2030.

28 For the 2018-2019 data: BPDB, *Annual Report 2018-2019*, 2019. For the 2020 data: BPDB website on September 19, 2020.
29 Data for capacity utilization during peak hours, total generation, and the per-unit generation cost for 2020 are not available as of October 2020.
30 1 Tk = 0.0117919 USD (Source: XE Currency Converter, July 2020)
31 BPDB, *Generation Planning Report up to 2030*, 2019.
32 Generation Planning Report up to 2030, BPDB
33 Government of Bangladesh, *Power System Master Plan 2016*
34 Bankuti, Chattopadhyay and Song, "Integrating Variable Renewable Energy in the Bangladesh Power System."
35 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.
36 Rijal, "Nepal likely to export power to Bangladesh using Indian grid."

Box 1: Competitive RE procurement in Bangladesh

Status

Recent competitive solar PV procurement resulted in the lowest bid prices ever seen in the country. In August 2019, a 45-55 MW project was awarded at 7.49 cents/kWh (6.36 BDT/kWh), to be commissioned by the second half of 2020. As of October 2020, the PPA has not been signed. For competitive wind procurement, on the other hand, the BPDB received only one bid for one of the three 50 MW projects auctioned in 2019.[37] In September 2020, BPDB announced the re-tendering of two 50 MW projects to be built in Chandpur and Inani (Cox's Bazar).[38] The Electricity Generation Company of Bangladesh (EGCB) launched a competitive procurement for a 10 MW wind project in November 2018;[39] it is to be executed as a joint venture between EGCB and the selected project developer.

Initial experiences

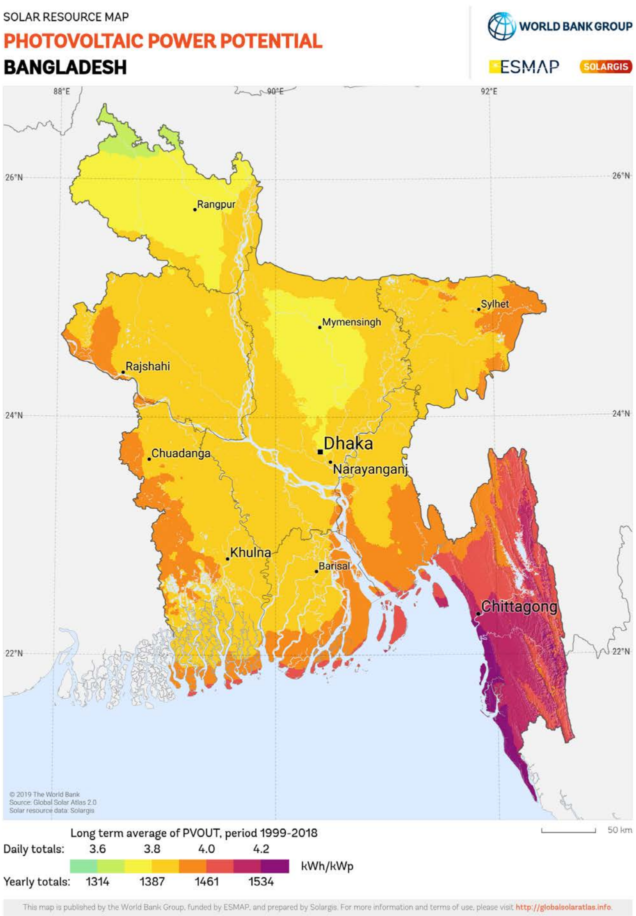
There are challenges in the process for both RE competitive procurement and unsolicited proposals. For example, developers must secure more than 40 permits from different government departments, often with long processing times.[40] Project developers also deem the current commissioning deadline of 12 months insufficient. In particular, the lack of bids in the 2019 competitive procurement of wind power arguably resulted from a lack of project information (e.g., site-specific resource data), a lack of sizable parcels of land, weak land acquisition regulations, tough terrain for siting and transportation, the responsibilities of the developer, as well as a lead time of only one month to submit bids.

More broadly, project development challenges have been an important barrier to scaling up both solar PV and wind power in Bangladesh. The main challenges relate to limited land availability, access to financing, and remote locations with high grid connection costs.

- Land for RE in Bangladesh competes with alternative uses, including agricultural, residential, and commercial/industrial use.[41] Agricultural land may not be used for solar PV projects,[42] which makes government-owned land in river islands and/or low-lying areas subject to seasonal flooding one of the only remaining options. This in turn increases project development costs.[43]
- Financial closure of RE projects continues to be challenging, as commercial banks lack experience and knowledge of utility-scale RE projects. Local banks have limited technical capacity to conduct due diligence and monitoring and to manage foreign currency transactions.[44] Off-taker risks reduce the bankability of RE projects.[45]
- Selected sites for wind auctions have faced challenges due to their remote location, missing transportation infrastructure, and grid connection costs.[46]

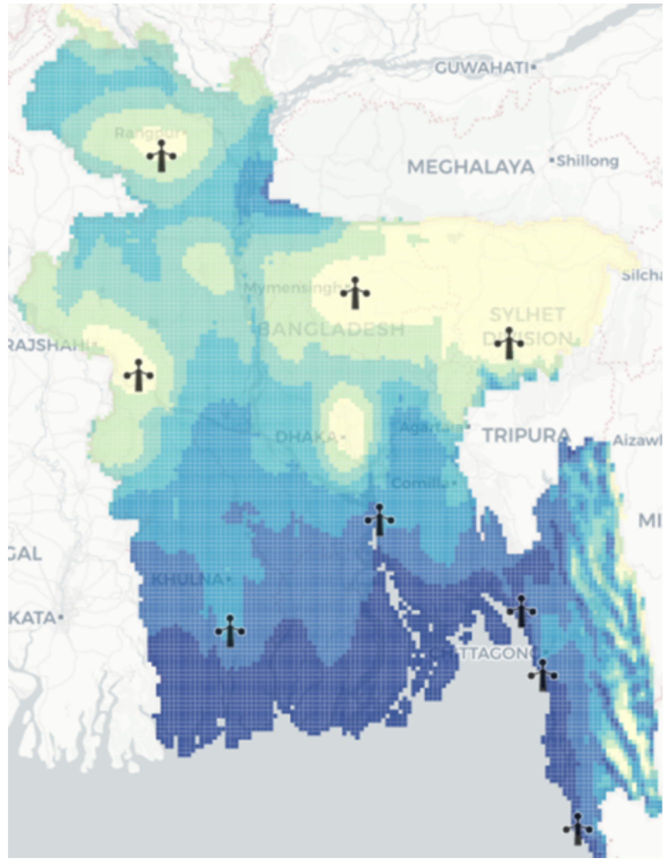
37 Personal communication with Alam Hossain Mondal, July 31, 2020.
38 BPDB, 2020.
39 EGCB, request for expressions of interest, 2018.
40 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.
41 World Bank, SREP PID/ISDS.
42 Bangladesh Economic Zone Authority (BEZA) plans to set up a solar power zone for generating at least 1,000 MW of electricity, for which it will acquire roughly 1,600 hectares of land. It is not clear whether this capacity will be auctioned; as of December 2018, a memorandum of understanding was signed between BEZA and developer Joules Power Ltd to build a 100 MW installation by 2020.
43 Pargal, "Lighting the Way: Achievements, Opportunities and Challenges in Bangladesh's Power Sector."
44 Ibid.
45 Ibid.
46 Based on bilateral meetings during a scoping trip with GoB officials in October 2019.

FIGURE 3: Solar Resource Map of Bangladesh



Source: Global Solar Atlas 2.0, Solargis

FIGURE 4: Wind Resource Map of Bangladesh



Source: NREL RE Data Explorer

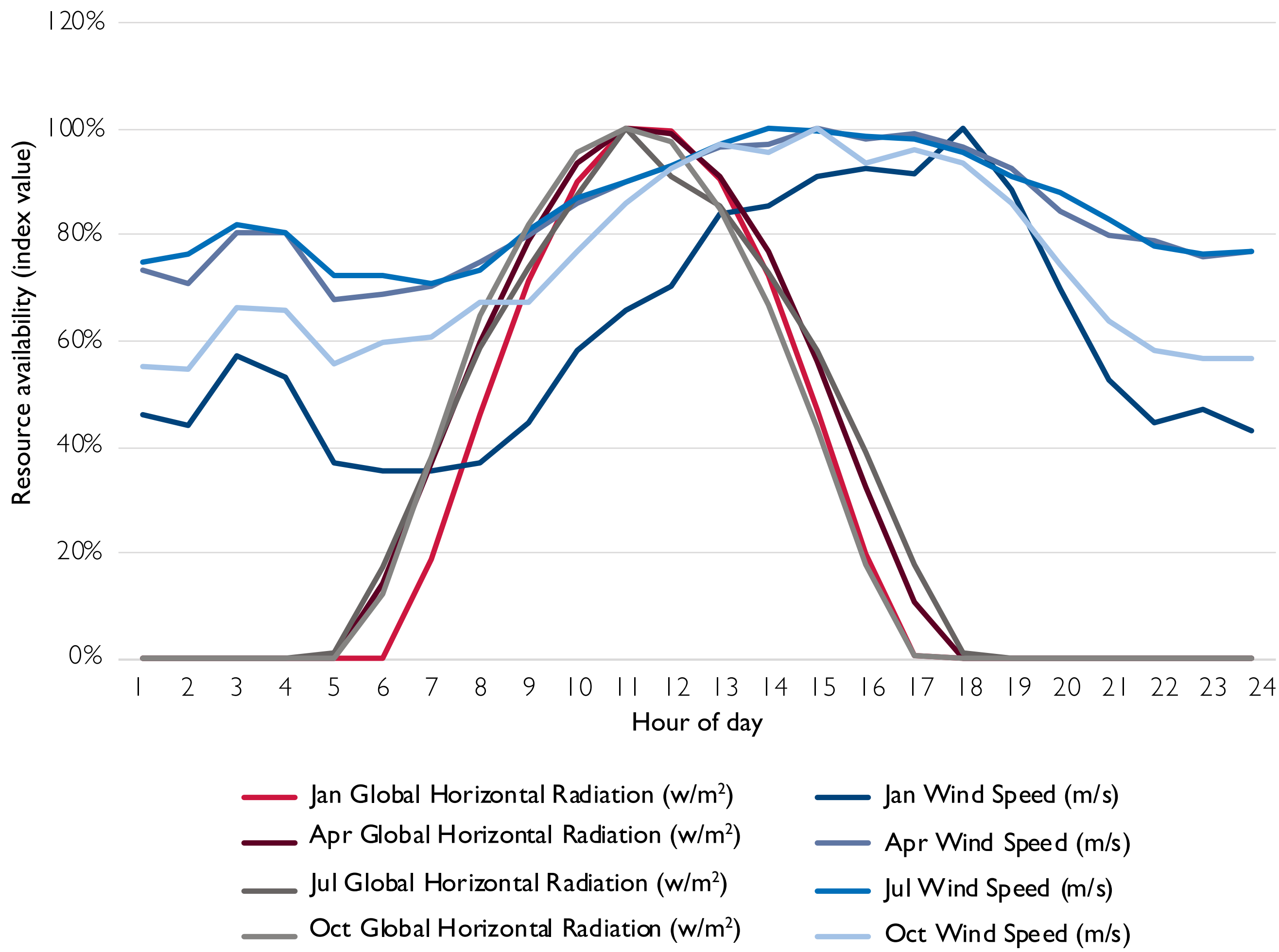
Despite government commitment, the uptake of utility-scale solar PV and wind power projects has been relatively low. As of February 2020, RE capacities for grid-connected installations amount to 80 MW of solar PV and 230 MW of hydropower, which falls well short of the 2021 target. Approximately 614.6 MW of solar PV capacity and 70 MW of wind capacity is currently under construction.[47]

Bangladesh has several RE instruments in place, including a solar home system roll-out program, and tax incentives, such as an exemption from corporate income tax for five years and the value-added tax (VAT) for RE equipment.[48] Since 2003, Bangladesh's Infrastructure Development Company Limited (IDCOL) has implemented the world's largest solar home system roll-out program. The program was suspended in 2020 due to the COVID-19 pandemic. Total solar off-grid capacity amounts to about 330.6 MW as of October 2020.[49]

As shown in Figure 3 and Figure 4, solar and wind resources are unevenly distributed across Bangladesh. For solar PV, the power potential is the highest in the southern coastal districts and especially the Chattogram area, where annual average output reaches around 1,500 kWh per kWp. In the north of Bangladesh, solar PV power potential is generally weaker, reaching between 1,300 and 1,400 kWh per kWp. For wind, the best resources (measured at a height of 100 meters) can be found in the coastal areas in the south and southeast, where average wind speeds reach up to six meters

47 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.
48 Ibid.
49 SREDA, *National Database of Renewable Energy*.

FIGURE 5: Daily Solar and Wind Availability in Chattogram, Bangladesh



Source: Guidehouse, based on Meteonorm data on hourly solar (GHI) and wind resource (m/s) data at the Chattogram weather station

per second. However, since these resource-rich regions are also prone to cyclones, solar and wind development in these areas should consider mitigation strategies in terms of site development through assessments of cyclone history, as well as design and engineering by adopting resilient equipment and plant configurations.

Figure 5 provides a preliminary indication of the daily availability of wind and solar resources in Chattogram, located on the southeastern coast of Bangladesh.[50] Solar PV availability at this location would allow solar PV projects to generate during the morning and early afternoon hours (8:00 a.m. to 3:00 p.m.). Wind availability, which is highest during the late afternoon and evening (5:00 p.m. to 10:00 p.m.), could partially contribute to supply the evening peak until 11:00 p.m., particularly in April and January. These daily resource availability patterns show a potential complementarity between wind and solar resources.

50 Resource availability was estimated based on hourly solar (GHI) and wind resource (m/s) data measured at the Chattogram weather station using Meteonorm. Hourly data shown in Figure 5 corresponds to the monthly average of each hour in a day for January, April, July, and October. Resource availability is not expressed in absolute values but in relation to the highest hourly value measured during a day ("index value" in the Y-axis of Figure 5). For example, at 3:00 p.m. in July, the average solar resource availability is 60 percent of the maximum value reached in a day.

FIGURE 6: Transmission Grid System of Bangladesh as of June 2019

Source: BPDB (2019): Annual report 2018-19

TABLE 5: Projected Changes in Regional Generation, Demand, and Interregional Transport Capacity (in MW)[51]

REGIONS	PEAK GENERATION		PEAK DEMAND		LINE CAPACITY BETWEEN REGION AND DHAKA	
	2015	2025	2015	2025	2015	2025
Dhaka	3,666	4,031	3,347	8,091	0	0
North/Northeast	1,545	2,684	731	1,180	1,200	7,200
Northwest	595	2,805	1,219	2,075	1,200	7,800
Southwest	929	4,268	812	1,607	900	3,900
Central	361	321	583	1,047	900	900
Southeast	551	2,738	744	2,321	900	4,500
Total	7,647	16,846	7,437	16,321		

2.3 Transmission grid system

The existing transmission grid consists of 12,293 circuit km of transmission lines (400 kV, 230 kV, and 132 kV). There are currently five 400 kV transmission lines in operation with a total length of 861.3 km.[52] Otherwise, the grid relies on an extensive network of 230 kV lines to transport power over longer distances. Figure 6 provides an overview of Bangladesh's transmission grid system.

The largest demand centers are in the Dhaka and Chattogram metropolitan areas, where 50 percent of power demand is concentrated. Currently, most generation capacity, concentrated in the Dhaka region as well as east and northeast of Dhaka, relies on supplies from domestic gas fields soon to be depleted.[53] As outlined above, the GoB intends to diversify its power supply by increasing power imports from India as well as importing gas and coal. Hence, while the predominant load centers will remain in the Dhaka region, increased power supply is expected from the northwest (as a result of power imports from India) and the south (where construction of new coal and gas plants is concentrated). Table 5 demonstrates this expected geographical shift in supply. While peak demand in Dhaka is projected to increase to 8.1 GW, local supply is expected to remain almost constant. By contrast, forecasts predict significant regional peak generation increases due to new coal-fired generation capacity in the southwest and southeast regions as well as gas-fired plants in the northeast and southeast regions.

This geographic shift in supply has major implications for Bangladesh's transmission grid, as it will have to be continuously upgraded from the west to Dhaka and from the south to Dhaka to facilitate the transport of power imports and new coal- and gas-fired generation as well as new RE capacity additions.[54] Currently, one high-voltage direct current (HVDC) line with a capacity of 1 GW connects India and western Bangladesh. In addition, several new gas and coal plants are being built in southern Bangladesh (Chattogram and Khulna region), requiring new 400 kV lines to Dhaka.

Existing plans for the transmission network focus primarily on new conventional power plants and not on the integration

51 Ibid.
52 Based on data from Power Grid Company of Bangladesh (PGCB) in October 2020.
53 Bankuti, Chattopadhyay and Song, "Integrating Variable Renewable Energy in the Bangladesh Power System."
54 Ibid.

of renewable projects specifically. In consultations, most stakeholders agreed that grid enforcements are on track to accommodate the planned conventional capacity additions. Since most of the expected solar and wind projects are far from the national grid, the current capacity of the transmission network will generally only be able to accommodate smaller renewable energy projects.[55] As a result, additional grid upgrades may be necessary in certain areas to connect more large-scale RE projects.

2.4 System operation

The power sector in Bangladesh has developed from a single vertically integrated utility, the BPDB, to a partially unbundled sector with private participation and competition in generation and, to a lesser extent, distribution. The BPDB still operates about half the country's power generation capacity and is the single off-taker procuring power from independent power producers (IPPs) and public generators based on negotiated power purchase agreement (PPA) tariffs. BPDB then sells the power to distribution utilities based on wholesale tariff rates regulated by the Bangladesh Energy Regulatory Commission (BERC). The Power Grid Company of Bangladesh (PGCB) is the single transmission company owning and responsible for operating and expanding the country's power transmission grid. The National Load Dispatch Center (NLDC), an entity affiliated with PGCB, is the system operator and is responsible for coordinating the power generation, transmission and distribution utilities.[56]

Grid codes are essential for the successful integration of VRE because they provide the rules for the power system operator to ensure operational stability and security of supply. A grid code has been in place in Bangladesh since December 2018. It states that the primary responsibility for load forecasting rests with each of the distribution utilities for their respective area. Load forecasts, including the determination of peak loads, energy projections, and daily load curves, are conducted annually and must be submitted to PGCB and NLDC by March 31 each year. NLDC is responsible for the coordination and preparation of annual, monthly and weekly load-generation balance and dispatch schedules. For the day-ahead schedule, all generators provide their available capacities to NLDC during each hour of the day, starting 36 hours ahead and for the first 12 hours of the following day. NLDC, together with BPDB, uses this information to prepare a day-ahead hourly dispatch schedule based on the merit order of available generators. NLDC may also instruct generators to hold certain reserves (spinning and/or standby).[57]

According to stakeholders consulted, Bangladesh's grid code does not contain specifics about RE system integration.[58] Nonetheless, the grid code mentions certain aspects of system operation practices for RE generators. Like conventional generators, RE generators must provide forecasted production on an hourly basis and must report unexpected unavailability to NLDC and BPDB, including deviations from initially submitted RE production forecasts. However, they are currently not penalized for forecast deviations. In addition, RE in Bangladesh enjoys priority dispatch except in cases of temporary grid unavailability. In such instances, BPDB/PGCB will request that the provider not evacuate power. If the requested hours exceed 100 hours in a year, BPDB will compensate the RE producer. Moreover, VRE generators are exempt from providing balancing services.

According to a recent World Bank study, system operation in Bangladesh faces several challenges related to power dispatch and grid stability despite the existence of a dedicated grid code. In terms of power dispatch, lack of automation or proper dispatch optimization tools often leads to inconsistency with the merit order. Dispatch processes are still largely handled manually using a merit order list on a spreadsheet. In some instances, grid bottlenecks or gas shortages have resulted in more expensive oil-fired plants being dispatched before cheaper gas-fired plants, leading to higher overall system costs.[59]

Inadequate frequency control and management of spinning reserves has led to grid stability issues, as most power plants do not participate in frequency support. In the absence of dedicated compensation for the provision of ancillary services, generators have little reason to adjust their generation downward to provide balancing services to the grid, given that they are paid for power produced. In the past, the unavailability

55 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.
56 BERC, *Electricity Grid Code 2018*.
57 Ibid.
58 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.
59 Bankuti, Chattopadhyay and Song, "Integrating Variable Renewable Energy in the Bangladesh Power System."

of sufficient spinning reserves has led to frequency fluctuations of ±2 Hertz (Hz) due to the lack of automatic frequency control mechanisms.[60] Such frequency fluctuations also make large-scale VRE system integration more difficult and potentially costly if not accompanied by more efficient and flexible generators providing spinning reserves.[61]

2.5 Summary of implications for VRE integration

A temporal mismatch between VRE generation and demand patterns results in potential supply inadequacy. Although total installed power capacities exceed peak demand, there is a mismatch between daily peak demand and peak supply. The mismatch during the daily peak demand period is especially pronounced during the summer months due to higher power demand, which results in regular load shedding. This requires additional capacities that deliver electricity during evening peaks, in addition to measures that steer power demand.

A spatial mismatch between VRE generation and demand centers results in grid infrastructure upgrades or extension requirements. Plans to extend the grid infrastructure align with the increased supply expected from the northwest (to accommodate power imports from India) and the south (to accommodate new coal and gas power plants). However, these plans only consider the envisaged conventional capacity, not the integration of renewable projects. This, and the fact that expected solar and wind projects are located far from the national grid, may result in necessary grid infrastructure upgrades or extensions in the southern and southeastern coastal areas, where future RE project development is expected to be centered.

Bangladesh lacks a regulatory framework to create incentives for generators, particularly in RE, to provide ancillary services. Generators have no incentives to participate in frequency control because there is no dedicated compensation scheme. System automation and integration is also lacking between all relevant stakeholders, including the NLDC, which affects the efficiency of frequency control procedures. The absence of adequate frequency control measures poses a challenge for large-scale VRE integration as it requires flexible spinning reserves able to balance out VRE generation.

Barriers in the project development process are high. Available land for grid-connected RE projects is scarce due to high population density, high flood risk, and alternative land uses such as agriculture. Moreover, there are few government initiatives to identify or zone land for RE projects. Tendered wind power sites have faced challenges due to their remote location (limited or no access roads), missing transportation infrastructure, and evacuation line costs.

Good wind and solar resources exist in Bangladesh's southern coastal areas. Based on a preliminary analysis of daily wind and solar resource availability in Chattogram, solar PV projects could potentially generate during the morning and early afternoon hours (8:00 a.m. to 3:00 p.m.). Wind availability, which is highest during the late afternoon and the evening (5:00 p.m. to 10:00 p.m.), could partially contribute to supply the evening peak until 11:00 p.m., particularly in April and January.

60 Ibid.
61 Nikolakakis, Chattopadhyay, and Bazilian, "A Review of Renewable Investment and Power System Operational Issues in Bangladesh."

CHAPTER 3.

DESIGN SOLUTIONS FOR SYSTEM-FRIENDLY RENEWABLE ENERGY PROCUREMENT

This section analyzes selected design solutions for innovative RE system-friendly procurement. Table 6 provides a summary of the design solutions.

The list of design solutions is not exhaustive; it focuses on innovative approaches to make the procurement of VRE more system-friendly. Design solutions not assessed in this paper include premiums paid to RE producers on top of power market revenues and the competitive procurement of ancillary services. These were not included for further analysis because they are either less relevant in the context of Bangladesh or target the procurement of products beyond VRE.

- **Premiums paid on top of power market revenues:** The direct sale of RE electricity to the wholesale market could provide location- and time-specific price signals. However, wholesale markets with low liquidity (in terms of market participants and trading volume) create lower revenue certainty for RE investors compared to fully liquid wholesale markets. Premium schemes like Contracts for Difference (CfD) in the UK or a sliding premium in Germany entail trading electricity at the power market and the payment of a premium or bonus per unit of electricity generated, in addition to market proceeds.[62] The premium paid to RE producers is the difference between the auction's strike price and the reference market price, which mostly protects power producers from the risk of volatile electricity prices.[63] Due to the lack of a liquid and centralized electricity spot market, premium schemes are currently less relevant to Bangladesh.
- **Competitive procurement of ancillary services:** Grid operators can obtain ancillary services via competitive procurement. For example, in Denmark, wind installations supply a significant volume of ancillary services.[64] The competitive procurement design is open to all technologies capable of providing the required products. However, this paper focuses on how to procure VRE that is more system-friendly rather than on measures targeting system integration of VRE more broadly. Hence, the procurement of ancillary services such as balancing power falls outside its scope.

62 Premium schemes can be symmetric or asymmetric. The CfD scheme used in the UK is an example of a symmetric floating premium tariff that guarantees a fixed price for power producers. If the market price is below the auction (strike) price, a premium payment is made to the producer. If the market price is above the auction (strike) price, the producer has to pay back the difference. Most European countries (e.g., France, Germany, the Netherlands) operate asymmetric floating premium schemes. Unlike the UK's CfD scheme, a producer does not have to pay back the difference if it sells electricity to the market at a higher price than the strike price.

63 The auction's strike price is set at the level where the volume demanded by the auctioneer is met by the volume offered by bidders.

64 Energinet; Klinge, "Wind power and ancillary services in Denmark."

TABLE 6: Overview of Design Solutions for innovative RE System-Friendly Procurement

DESIGN SOLUTION	DESCRIPTION	BEST PRACTICE EXAMPLE
1. Time-based incentives	Time-based incentives support RE generation that more closely matches the power demand curve (e.g., price adjustment factors, supply blocks).	**Chile** implemented intraday and seasonal supply blocks to incentivize owners of VRE generators to supply electricity when most needed and guarantee continuous supply to distribution companies.
2. Location-based incentives	Location-based incentives steer the location of projects to specific areas and grid connection points to avoid concentrating projects in areas that are resource-rich but costly to connect. They include options such as bonuses/ penalties for bids located in areas with available/insufficient grid capacities, RE development zones with simpler permitting processes, capacity quotas at regional or grid connection point levels, or site-specific competitive procurement.	**Kazakhstan** implemented capacity quotas to limit transmission costs from auctioned installations and to ensure the system can absorb the additional generation capacity.
3. Physical hybrids	Competitive procurement of RE electricity from installations combining technologies such as wind and solar (and potentially storage) offset the technology-specific intermittencies of VRE and allow for more efficient utilization of land and transmission capacity.	Physical hybrids in **India** currently contribute to efficient use of land (kWh/m^2) and grid connection capacity (MWh/MW), as well as mitigating the intermittency of VRE generation. The recent competitive procurement organized by the Solar Energy Corporation of India (SECI) for solar-wind hybrid projects focused on eligibility criteria, coupled with penalties.
4. Virtual hybrids (supply-side aggregators)	Virtual hybrids, or aggregators, bundle different power system units at different grid connection points (e.g., dispatchable and non-dispatchable RE, demand response resources, storage), which are dispatched via virtual control systems. Virtual hybrids can promote RE integration by providing both demand- and supply-side flexibility. This paper focuses on supply-side virtual hybrids, which aggregate a portfolio of diverse generation assets and potentially storage to provide firm power.	The virtual power plant Next Kraftwerke in **Germany** has a portfolio of around 8,700 assets that include solar PV, batteries, combined heat and power (CHP), biogas, hydro, emergency generators, and customer loads.[65] Aggregators create a quasi-dispatchable virtual power plant.

65 Guidehouse Insights, "VPP Platform Providers. Assessment of Strategy and Execution for 15 Companies."

The following sections present an overview of selected design solutions in innovative RE system-friendly procurement. For each design solution, a description is provided, followed by international experiences.

3.1 Design Solution 1: Time-based incentives and penalties

3.1.1 Description

Time-based incentives include design options to incentivize RE generation that more closely matches the power demand curve. Measures can include price adjustment factors and supply blocks.

Time-of-day and time-of-year price adjustment factors reward or punish electricity generation supplied at specific times of the day or year. The adjustment factor is typically applied to the actual price paid to the producers and not to the bid price offered. By increasing or decreasing the price paid per kilowatt-hour (kWh) of generation, energy policy planners seek to reward supply that more closely matches demand.

Supply blocks require producers to guarantee continuous delivery of electricity during certain periods or face penalties. Time-specific supply blocks limit the supply commitments of VRE installations to the times of day or year when they effectively generate electricity.[66]

3.1.2 Country experience: Intraday and seasonal supply blocks in Chile

Objective: Allow intermittent technologies to optimize their feed-in potential and guarantee continuous supply to distribution companies.

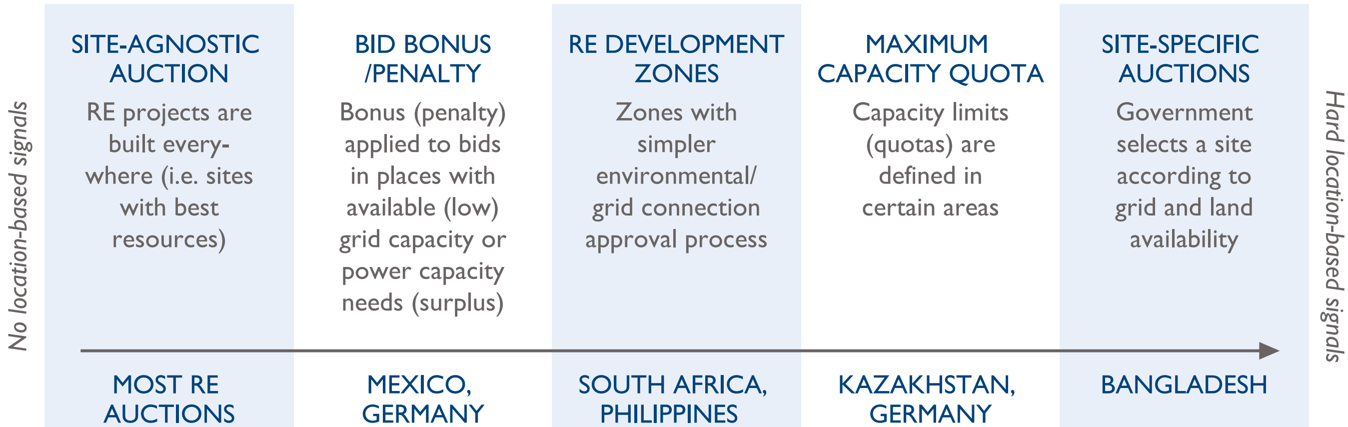
Design: Distribution companies provide demand projections for the next 10 years for energy, reactive power, and peak

TABLE 7: Results of Chile's 2017 RE Competitive Procurement

SUPPLY BLOCKS DEFINED IN CHILE'S 2017 RE COMPETITIVE PROCUREMENT[67]				
Supply Block Type	**Supply Block Duration**	**Base Energy Auctioned (Gwh/Year)**	**Variable Energy Auctioned (Gwh/Year)**	**Total Energy Auctioned (Gwh/Year)**
Hourly	12:00 a.m. – 7:59 a.m. and 11:00 p.m. – 11:59 p.m.	480	48	528
	8:00 a.m. – 5:59 p.m.	707.3	70.7	778
	6:00 p.m. – 10:59 p.m.	358.2	35.8	394
Quarterly	Jan 1 – Mar 31	113.6	11.4	125
	Apr 1 – Jun 30	113.6	11.4	125
	Jul 1 – Sep 30	113.6	11.4	125
	Oct 1 – Dec 31	113.6	11.4	125
Total		**1,999.9**	**200.1**	**2,200**

66 IRENA, 2015.
67 ACERA, 2018.

FIGURE 7: Competitive Procurement and Range of Location-Based Incentives



demand. The regulator aggregates the projected supply requirements and conducts the competitive procurement. In the tender documentation, distribution companies provide bidders with information from the preceding five years on load factor, maximum energy demand for energy sold to regulated customers, and maximum energy demand in peak demand hours for energy sold to regulated customers.[68]

The supply blocks consist of three intraday (12:00 a.m. – 8:00 a.m. and 11:00 p.m. – 12:00 a.m.; 8:00 a.m. – 6:00 p.m.; 6:00 p.m. – 11:00 p.m.) and four three-month seasonal blocks. Each block has a base (annual energy requirement) and a variable component (10 percent of the base component). Generators can submit bids from a single project or a portfolio of projects.

Supply blocks transfer generation risks to the RE producer, and production deviations are settled at spot market prices. Hourly and seasonal supply blocks allow RE producers to concentrate their contractual commitments to the times of the day or year when they effectively generate electricity.

Results: The competitive procurement successfully contracted distribution companies' hourly and quarterly electricity requirements. Awarded bids, all of which are backed by new RE projects, will provide continuous power within the defined block at an average cost of 3.25 U.S. cents/kWh (2.76 BDT/kWh)—the lowest price ever recorded in the country. As a reference, the average spot market price in 2017 was considerably higher, roughly 5.51 cents/kWh (4.68 BDT/kWh) in the Central Interconnected System and 5.74 cents/kWh (4.87 BDT/kWh) in the Norte Grande Interconnected System.

Bids from solar projects were the most competitive at 2.15 cents/kWh (1.83 BDT/kWh), followed by wind at 3.29 cents/kWh (2.79 BDT/kWh). This result allows distribution companies to buy electricity at a lower cost than from thermal technologies, which had the second-highest average bid price submitted at 7.54 cents/kWh (6.4 BDT/kWh), after biomass at 7.79 cents/kWh (6.62 BDT/kWh). Bids from solar with battery storage averaged 3.65 cents/kWh (3.10 BDT/kWh). Although very competitively priced, these bids were not awarded due to restrictions specified by the bidders.

Competitive procurement effectiveness will also depend on the timely commissioning of the contracted projects and the actual delivery of electricity in the defined blocks. The six-year project realization period means projects must be commissioned by January 2024, so their success or failure cannot yet be assessed.

3.2 Design Solution 2: Location-based incentives

3.2.1 Description

Site-agnostic procurement schemes tend to concentrate the development of RE projects in areas that are rich in RE resources, which can burden the grid infrastructure and create competition for land use. Location-based incentives aim to steer projects to specific areas and grid connection

68 Government of Chile, *Resolución Exenta No. 438 Modifica Bases de Licitatión 2017-01*.

points to avoid this project concentration. Figure 7 shows different types of location-based incentives. The signal these mechanisms provide can be based on price or quantity. They include a bonus/penalty for bids located in areas with available/insufficient grid capacities (e.g., Mexico), RE development zones with simpler permitting processes (e.g., South Africa, Philippines), capacity quotas at the regional or grid connection point level (e.g., Kazakhstan, planned design in Vietnam), or site-specific competitive procurement (e.g., Bangladesh).

3.2.2 Country experience: Location-based incentives in Kazakhstan

Objective: Capacity quotas were set at multiple nodes of the system to minimize new transmission costs and ensure the system could absorb the electricity generation resulting from the auction. The Kazakhstan power system has surplus generation capacity.

Design: The auction documents contain information on the land plots allocated for the construction of an RE installation and grid connection points indicating the maximum permissible capacity and the number of possible connections. The grid connection points are provided by the transmission grid operators to the Ministry of Energy and are reserved until the winning bidders conclude a grid connection agreement. Bidders also need to specify the minimum permissible volume of installed capacity for their installation with their bid.

If the volume of bids exceeds the maximum permissible capacity at this connection point, bids will be excluded from the preliminary list of winners in descending order of prices until the maximum permissible installed capacity for the connection point is met. A partially satisfied bid, that is, a bid whose capacity is only partly covered within the maximum permissible capacity, will be awarded if the reduced volume of partially satisfied bids is greater than or equal to the minimum permissible volume of the bid.

Results: The competitive procurement in Kazakhstan contracted 857.93 MW of RE projects that will be located at nodes with enough grid capacities and so can help minimize the need for grid expansion. Table 8 presents a summary of the results and the planned commissioning deadline for each RE technology. More than half of the volume was awarded to wind projects (500.9 MW) followed by solar (270 MW), hydro (82.1 MW), and one 5 MW project for biogas. The lowest awarded bids were for hydro (12.8 KZT/kWh,[69] roughly equivalent to 3.4 cents/kWh or 2.89 BDT/kWh), wind(17.39 KZT/kWh, roughly equivalent to 4.6 cents/

TABLE 8: Results of Kazakhstan's 2018 Competitive Procurement

COMPETITIVE PROCUREMENT RESULTS IN KAZAKHSTAN, 2018[70]			
Ceiling Price	Awarded Volume (MW)	Weighted Average Price	Commissioning Deadline
Wind: 6 cents/kWh (5.10 BDT/kWh)	500.85	Wind: 5.29 cents/kWh (4.93 BDT/kWh)	Wind: 3 years after PPA
Hydro: 4.4 cents/kWh (3.74 BDT/kWh)	82.08	Hydro: 3.9 cents/kWh (3.31 BDT/kWh)	Hydro: 4 years after PPA
Solar: 9.2 cents/kWh (7.81 BDT/kWh)	270	Solar: 5.91 cents/kWh (5.02 BDT/kWh)	Solar: 2 years after PPA
Biogas: 8.69 cents/kWh (7.38 BDT/kWh)	5	Biomass: 8.54 cents/kWh (7.25 BDT/kWh)	Biomass: 3 years after PPA

69 1 USD = 376.47 KZT. Source: USAID and KOREM.
70 Ceiling prices for 2018 auctions in local currency: wind capacity – 22.68 KZT/kWh; solar capacity – 34.61 KZT/kWh; hydropower capacity – 16.71 KZT/kWh; and biogas capacity – 32.23 KZT/kWh. Average prices for 2018 auctions in local currency: wind capacity – 19.92 KZT/kWh; solar capacity – 22.25 KZT/kWh; hydropower capacity – 14.68 KZT/kWh; and biogas capacity – 32.15 KZT/kWh. Source: USAID and KOREM.

kWh or 3.91 BDT/kWh), and solar (18 KZT/kWh, roughly equivalent to 4.8 cents/kWh or 4.06 BDT/kWh).[71]

Seven rounds (out of 20) were canceled because the number of participants and offered volume were too low. Public information on how many bids were excluded or partially awarded due to the capacity quotas is not available.

3.3 Design Solution 3: Physical hybrids

3.3.1 Description

Technologies such as wind, solar and potentially storage aim to combine complementary generation profiles to offset technology-specific intermittencies and provide a more continuous power supply. Moreover, physical hybrids allow for a more efficient use of land and transmission infrastructure compared to single-technology installations because energy generation per unit area of land and evacuation infrastructure can be increased.

The design of competitive procurements for hybrids can incentivize system-friendly attributes. Two main options are possible. The first includes multi-criteria auctions, which evaluate projects against several different criteria, and time-based compensation/penalties for providing generation that more closely matches the load profile. The second option is to define eligibility criteria such as a minimum capacity utilization factor (CUF).[72] In case of a generation shortfall from the declared minimum generation requirement, penalties apply.

RE projects with a higher CUF, such as physical hybrids, have lower grid connection costs than single solar PV and wind projects. Hybrids make fuller use of the grid and create savings in connection costs and operations and maintenance costs.[73]

3.3.2 Country experience: Physical hybrid procurement in India

Objective: Efficient utilization of land (i.e., kWh/m^2) and transmission capacity (i.e., MWh/MW), as well as reduced intermittency of VRE generation to increase grid stability.

Design: The competitive procurement SECI organized for solar-wind hybrid projects in 2019 focused on a minimum generation requirement, coupled with penalties.[74] The minimum generation requirement was a CUF of at least 30 percent. Penalties applied if the actual generation fell below 90 percent of or more than 20 percent higher than the declared CUF. If SECI decided to off-take excess generation beyond the 120 percent CUF threshold, it could do so at the full PPA tariff.

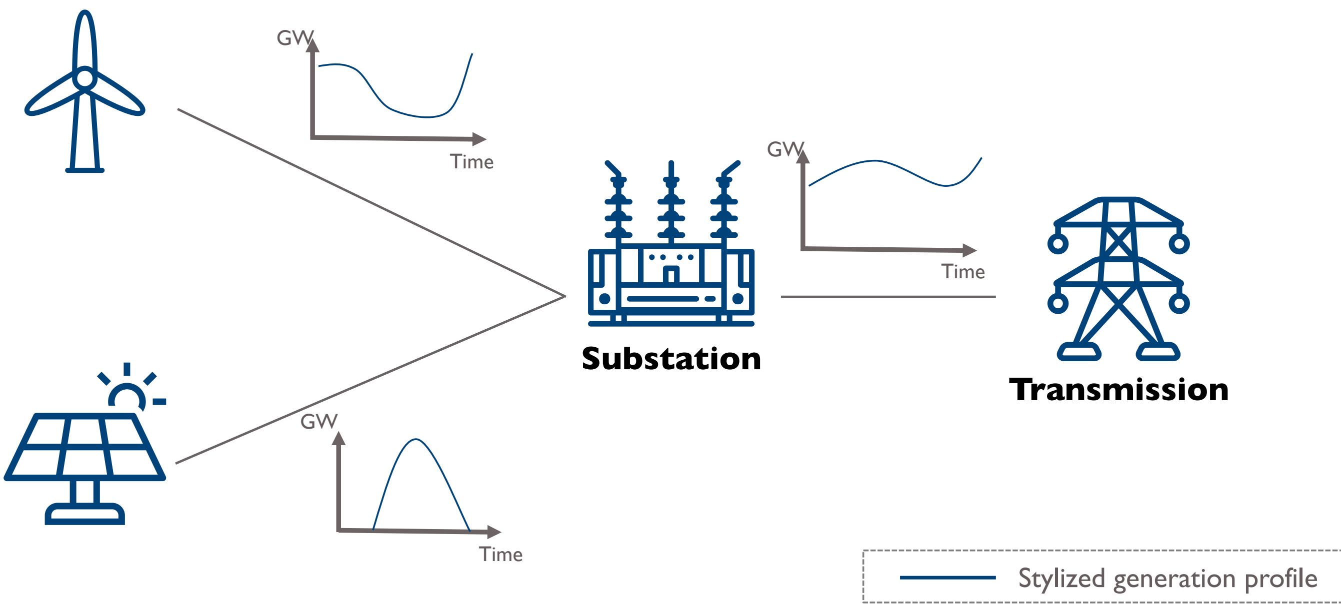
In October 2019, India issued new draft guidelines for its solar-wind hybrid procurement.[75] While the minimum CUF remains at 30 percent, bidders can now revise the CUF defined at the time of signing the PPA during the first three years of operation. This supports compliance with the CUF by allowing bidders to consider plant performance and better site measurements during plant operation.

India has also implemented the competitive procurement of physical hybrids in combination with time-based incentives. SECI held an auction in 2019 for hybrids with assured peak power supply. Energy generated during off-peak hours (9:01 a.m. – 6:00 p.m. and 12:01 a.m. – 5:59 a.m.) will be remunerated with a flat, administratively set, off-peak tariff payment of 2.70 INR/kWh (3.89 cents/kWh).[76] Energy generated during peak hours (6:01 a.m. – 9:00 a.m. and 6:00 p.m. – 11:59 p.m.) will be paid at a peak tariff rate determined through competitive procurement.

Results: In the first competitive procurement round held at the central level in 2018, SECI awarded 840 MW split between two projects at 2.67 INR/kWh (3.55 cents/kWh) and 2.69 INR/kWh (3.57 cents/kWh).[77] In the second round, held in 2019, SECI awarded a 600 MW project at the same price and a 120 MW project at 2.70 INR/kWh (3.59 cents/

71 USAID and KOREM, Report on Renewable Energy Auctions in Kazakhstan.
72 Capacity utilization factor refers to the ratio of a plant's actual output over a year to the maximum possible output under ideal conditions.
73 Trabish, H. "Utilities take note: Hybrid renewables projects are coming."
74 SECI, 2018.
75 Ministry of Renewable Energy, India.
76 1 USD = 75.3 INR (Source: Oanda Currency Converter, June 10, 2020)
77 Prateek, "India's First Mega Solar-Wind Hybrid Auction Sees Lowest Tariff of ₹2.67/kWh."

FIGURE 8: Simplified Representation of a Physical Hybrid



kWh).[78] Solar PV generation was contracted for as low as 2.50 INR/kWh (3.32 cents/kWh) in 2019,[79] and wind for 2.51 INR/kWh (3.33 cents/kWh) in 2018.[80] In comparison, the National Thermal Power Corporation (NTPC) reported an average generation cost of 3.42 INR/kWh (4.54 cents/kWh) in 2018, with a large majority of its operational capacity based on coal- and gas-based power plants.[81]

In January 2020, SECI successfully contracted 1.2 GW of hybrid capacity with assured peak power supply. The tender, launched in 2019, was oversubscribed by 420 MW and resulted in weighted average bid prices as low as INR 4.04/kWh (5.36 cents/kWh).[82] This included allowing the use of energy storage or any other RE generation available during peak hours, the incorporation of peak and off-peak tariffs, and CUF limits of at least 35 percent.

Currently, grid connection costs are not charged to RE producers in India. Instead, grid connection costs are socialized, which means they are passed on to the consumer. Therefore, RE producers are not yet compensated for the system value of hybrid installations. Starting in 2022, RE producers will be required to pay for grid connection costs. The system value of physical hybrids will be taken into account and compensated, making hybrid projects more competitive with single PV and wind installations that also need to pay for grid connection costs.

3.4 Design Solution 4: Virtual hybrids (Supply-side aggregators)

3.4.1 Description

Virtual hybrids bundle various power system units at different grid connection points, and virtual control systems then dispatch the units. As a result, virtual hybrids can act as a single entity similar to a conventional generator when selling electricity to the power market or a single-buyer, or when providing ancillary services to the operator.[83] Virtual hybrids can include non-dispatchable as well as dispatchable RE installations, demand-response resources, and storage units. A control center processes information related to weather forecasts, electricity price development, and generation and consumption trends to optimize the operation of the units forming part of the virtual hybrid.

78 Chandrasekaran, "Tariffs remained unchanged in hybrid auction."
79 Prateek, "SECI's 750 MW Solar Auction for Rajasthan Sees Lowest Tariff of ₹2.50/kWh."
80 Prateek, "₹2.51/kWh Wins SECI 2 GW ISTS Wind Auction."
81 Prateek, "Mahindra Susten Emerges as Lowest Bidder in NLC India's 20 MW Solar with BESS Auction."
82 Parikh, "Greenko, ReNew win SECI's 1.2 GW solar, wind auction with storage for peak power supply."
83 IRENA, *Aggregators—Innovation Landscape Brief.*

Virtual hybrids can promote RE integration by providing demand- and supply-side flexibility. On the supply side, virtual hybrids optimize electricity generation output to feed in as much electricity as has been purchased. Demand-side flexibility includes aggregating demand-response resources or storage units to provide grid services. This paper focuses on supply-side virtual hybrids, which aggregate a portfolio of diverse generation assets and potentially storage to provide a firm power supply.

3.4.2 Country experience: Virtual power plant in Germany

The virtual power plant Next Kraftwerke in Germany bundles RE in a portfolio to provide flexibility services in the market. Hybrid solutions with storage create a quasi-dispatchable virtual power plant.

Objective: Integrating smaller intermittent RE to provide balancing energy products to the balancing market.

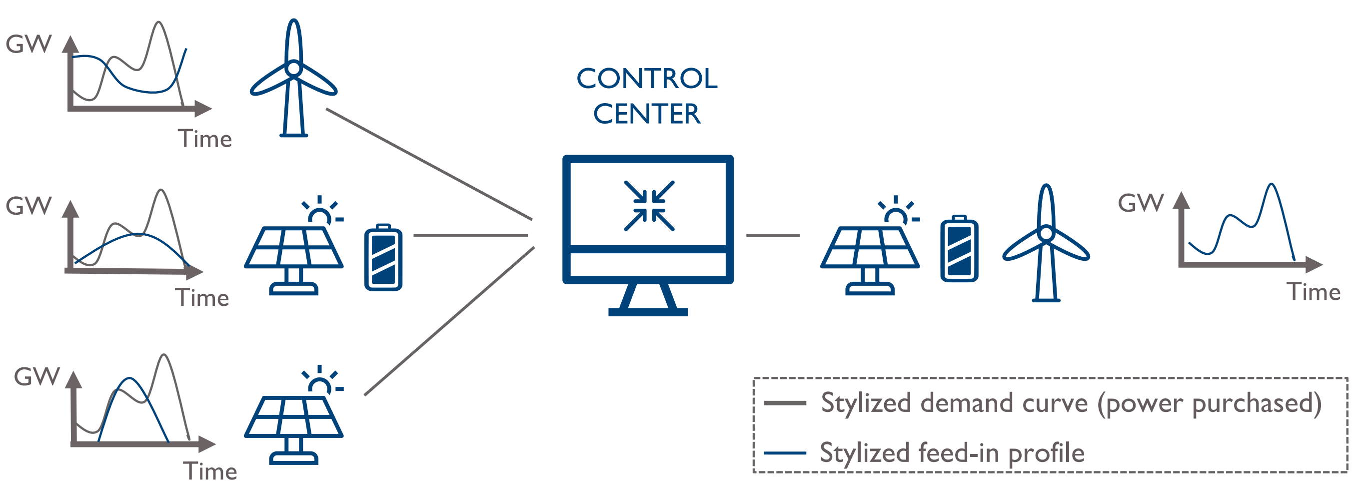
Design: Since 2012, RE producers can offer balancing energy on the balancing energy market in Germany. The products are procured in daily and weekly competitive procurement rounds by the grid operator. The products procured are primary reserve (delivered within 30 seconds), secondary reserve (delivered within five minutes), and tertiary reserve (delivered within 15 minutes and up to one hour).

Next Kraftwerke's virtual hybrid digitally aggregates multiple (small and large) RE and conventional installations operated by different producers into a single centralized control system. Different generation technologies (e.g., solar PV, wind, hydro, biogas, and CHP) and power consumers are bundled to offset intermittency risks. The asset aggregation allows them to be forecasted, optimized, and traded as one single power plant. Fluctuations in VRE generation can be balanced by ramping up and down power generation and power consumption of controllable units. Moreover, VRE can better integrate into existing markets, because smaller individual plants generally cannot provide balancing services or offer flexibility on the power exchange.

Installations wishing to participate in the balancing market need to be technically prequalified to ensure compliance with the transmission code. In case of a frequency imbalance, the virtual hybrid receives an order from the grid operator requesting a certain amount of power to balance out frequency deviations. The call is divided into smaller parts because the individual assets of the virtual hybrid can only provide a fraction of the power needed. The algorithm of the virtual power plant decides which asset will provide how much power. Revenues earned in the balancing market are shared between the virtual hybrid and the RE producers.

Results: As of 2016, Next Kraftwerke provided aggregated power of 67 MW as primary reserve, 67 MW as secondary reserve, and 1,160 MW as tertiary reserve, thereby reducing thermal generation reserve provision. This includes biogas, hydro, emergency aggregators (using diesel), and CHP plants.[84]

FIGURE 9: Simplified Representation of a Virtual Hybrid



84 Next Kraftwerke.

CHAPTER 4.

APPLICABILITY OF SYSTEM-FRIENDLY PROCUREMENT TO BANGLADESH

The applicability of system-friendly design solutions to Bangladesh is analyzed based on their suitability for supporting system integration of VRE and their feasibility to be implemented in the country. A design solution's suitability refers to its effectiveness in addressing system challenges that result from the timing, location, and quality of VRE electricity injected into the grid. The feasibility of a solution is assessed based on pre-conditions or requirements to successfully implement that solution in Bangladesh. Requirements can refer to the availability of information on power system operation or planning, RE resource availability in the country, the regulatory framework, or the RE project development process.

4.1 Suitability of system-friendly procurement in Bangladesh

The integration of increasing shares of VRE creates system challenges. These include the temporal mismatch between VRE generation and demand (its timing), the intermittency of VRE generation (its quality), and the physical distance between VRE generation and demand centers (its location). System-friendly procurement design aims to increase the system value of VRE by mitigating its adverse effects on the power system's supply adequacy, addressing the requirement for balancing services, and reducing the need for grid infrastructure upgrades or extensions. Figure 10 presents an overview of system challenges, impacts, and the design solutions that may be suitable to address them. For each system integration challenge, the table analyzes the relevance of the different design solutions.

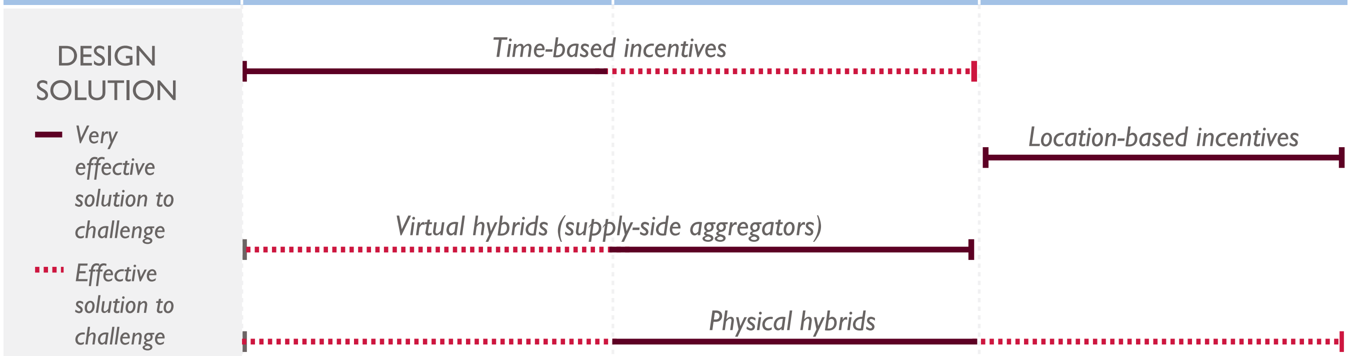
4.1.1 Challenge: Timing

The temporal mismatch between daily peak demand and peak supply in Bangladesh (especially during the summer months) has led to regular load shedding. Annual electricity demand and peak loads are expected to increase due to economic and population growth. System-friendly RE procurement can reduce the need for dispatchable conventional power plants to meet future peak demand and therefore ensure the adequacy of the system. Most consulted stakeholders agree that, particularly in urban areas, the current trend toward a higher evening demand peak is likely to continue in the future. However, some stakeholders note that policymakers' renewed focus on DSM and the country's economic transition and industrialization (e.g., the establishment of economic zones) may shift demand to the day and thus reduce evening peaks.

Time-based incentives such as tariff adjustments and supply blocks can result in procuring power with a higher value for the system, in line with the buyer's expectations on demand and supply patterns at the time of the auction. One challenge Bangladesh's distribution companies face is

FIGURE 10: Overview of System Integration Challenges of VRE and Suitability of Design Solutions

SYSTEM CHALLENGE	Timing: Temporal mismatch of VRE generation and demand pattern	Quality: Intermittency of VRE generation	Location: Spatial mismatch of VRE generation and demand centers
SYSTEM IMPACT ON	Supply adequacy	Balancing requirements	Grid infrastructure



responding to peak demand between 5:00 p.m. and 11:00 p.m.[85] Dispatchable conventional power plants and power imports and exports are one supply-side option to respond to changes in demand. In addition, tariff adjustments or supply blocks can incentivize the delivery of RE electricity during peak load periods, when it is most valuable to the system. This design solution can thus be suitable to support supply adequacy in Bangladesh's power system.[86]

Energy procurers can identify daily peak and off-peak demand periods, which they can use to determine tariff adjustments or supply blocks. Solar PV and wind generation supplied during off-peak periods has a lower value to the system compared to electricity delivered during peak hours. Tariff adjustments and supply blocks can incentivize RE producers to optimize their generation by, for example, adding batteries that allow them to supply electricity with a higher value.

Improving the match of VRE generation with the demand curve can also help avert the need for inefficient and costly capacity addition. Distribution companies in Bangladesh face financial difficulties because end-user tariffs do not cover costs incurred to supply electricity. Time-based incentives can enable distribution companies to channel PPA payments to installations supplying power that more closely matches the companies' needs.

Virtual hybrids (supply-side aggregators) and, to some extent, **physical hybrids** can also be suitable to address supply adequacy. Virtual hybrids can shift VRE supply to cover peak demand periods in the evening through a portfolio that combines different generation and storage assets. By combining solar and wind, physical hybrids can also extend the period during which supply can be guaranteed. If combined with storage or dispatchable RE such as biomass, physical hybrids' contribution to VRE shifting can be similar to that of aggregators.

4.1.2 Challenge: Quality

The intermittency of VRE generation can increase the need for reserve and residual load following requirements to balance supply and demand. Bangladesh's power system faces challenges in the management of frequency control, in part

85 BPDB, *Annual Report 2018-2019*.
86 Time-of-use tariffs could provide an alternative demand-side solution to the timing challenge. With this solution, different rates are charged to consumers depending on the time at which power is used. This practice can be used to shift peaks (and valleys) in demand and smooth demand profiles, which can simplify system operations and increase overall efficiency.

due to the absence of adequate frequency control measures. System-friendly RE procurement can reduce the need for additional flexibility associated with VRE.

Physical hybrids can reduce intermittency for the same hour throughout the year compared to single-technology wind or solar PV plants. A more stable and firm electricity feed-in can lower grid integration costs by reducing the need for extensive cycling of conventional power plants to meet residual load and to balance out VRE forecast errors. If suitable sites in southern Bangladesh are available, physical hybrids can enable a more balanced daily power supply. For example, a preliminary analysis of solar PV availability at Chattogram shows that solar PV projects could generate during the morning and early afternoon hours (8:00 a.m. to 3:00 p.m.).[87] Wind availability, which is highest during the late afternoon and the evening (5:00 p.m. to 10:00 p.m.), could partially contribute to supply the evening peak (which lasts until 11:00 p.m.), particularly in April and January.

Virtual hybrids (supply-side aggregators), which bundle VRE, dispatchable RE generation and potentially storage assets at different grid connection points, allow a virtual hybrid to provide a firm and dispatchable supply of electricity. Generation fluctuations at a single VRE plant in the virtual hybrid can be balanced by ramping up and down power generation from dispatchable generation and storage units and by using the complementary output and spatial smoothing effects of VRE resources in different locations.

Time-based incentives can, to some extent, reduce intermittency by reducing the power system's residual load. VRE intermittency requires other conventional power plants to be more flexible because they have to ramp power up and down more quickly and operate at lower output levels. By incentivizing the supply of electricity when it is most valuable to the system, tariff adjustments or supply blocks can help reduce the residual load to be covered by load-following generators. VRE installations combined with batteries allow bulk shifting of RE power for better load following.

4.1.3 Challenge: Location

The spatial mismatch between demand centers and places where utility-scale VRE electricity is injected into the grid can become an issue in Bangladesh. The current plans for grid expansion consider the envisaged conventional capacity additions, but not the integration of RE projects.[88] This, and the fact that solar and wind projects are often located far from the national grid, may necessitate grid infrastructure upgrades or extensions in the southern and southeastern coastal areas, where future RE project development is expected to be centered.[89]

Bangladesh has already implemented **location-based incentives** in the form of site-specific auctions for wind and solar, in which the government or distribution company selects the available project site. Site-specific auctions can enable a faster and system-friendly deployment by steering RE projects to areas with easier project development, as long as the site selection and pre-development by the government are of adequate quality and the project site attributes are communicated well. In the case of wind, however, selected sites have faced challenges due to their remote location, missing transportation infrastructure, and grid connection costs.

Physical hybrids can result in a more efficient use of land and grid infrastructure per unit of VRE generation. By using a common grid connection infrastructure, physical hybrids can help reduce grid connection and transmission costs. Moreover, co-locating solar PV and wind installations by, for example, installing solar PV panels in the shadow-free area available around wind turbines, could reduce the pressure to find suitable land. However, this is subject to the availability of sites with both good wind and solar resources. Indeed, a significant challenge faced by RE projects in Bangladesh is land scarcity due to competing uses and seasonal flooding as well as the fact that agricultural land may not be used for solar PV projects.

Planning transmission grid upgrades and developing RE through competitive procurement should run in parallel. Bangladesh should assess the suitability of physical hybrids, including those with storage, while considering the costs of expanding the transmission grid to connect the installation.

87 Guidehouse, based on Meteonorm data on hourly solar (GHI) and wind resource (m/s) data at the Chattogram weather station.
88 USAID, *Challenges in the Development of Variable Renewable Energy in Bangladesh*, 2020.
89 Ibid.

Grid modernization is a multi-year process that often requires substantial investment. Steering RE development to areas close to demand centers, rather than developing areas with good solar and wind resources, can therefore have a higher system value. An optimization model that finds the least-cost investment and dispatch solution over a 20-year planning horizon, for example, can help policymakers assess the suitability of design solutions and measures outside competitive procurement programs to minimize system costs.

4.1.4 Conclusions for Bangladesh

Time-based incentives can be particularly suitable to increase the contribution of VRE to supply adequacy, while adequately planned site-specific auctions **(location-based incentives)** can mitigate the pressure on grid infrastructure expansion requirements. Virtual and physical hybrids tap into system benefits resulting from the combination of VRE technologies, such as complementary feed-in patterns and, in the case of virtual hybrids, spatial smoothing effects over larger geographical areas to provide more firm power, reducing the need for balancing requirements.

Although design solutions like **virtual hybrids** and **physical hybrids** can help address multiple system challenges, the applicability of a design solution also depends on whether conditions required for their implementation are met. The following section will analyze the feasibility of the design solutions.

4.2 Feasibility of system-friendly procurement in Bangladesh

4.2.1 Time-based incentives

For adequate implementation, time-based incentives require information on power system characteristics such as projected demand and generation patterns. When setting time-based incentives such as tariff adjustments or supply blocks, the system planner and the procuring entity need to be able to rely on information that is accurate and updated as demand patterns change. Necessary information includes current and projected hourly and seasonal demand and generation patterns at the transmission level.

Distribution companies in Bangladesh are responsible for preparing load forecasts in their respective service area, which includes the daily load curve, annual peak load, and energy projections for each connection point on the transmission grid, according to the grid code. The load forecasts are updated annually or whenever major changes are made in the existing forecasts. This information can be used to define peak and off-peak periods, from which tariff adjustments or supply blocks will be determined.

4.2.2 Location-based incentives

Site-specific auctions require that the government conduct adequate project pre-development and provide sufficient information on project site characteristics to bidders.[90] Incorrect information can create project development risks for auction winners that might lead to delays or cancellations.

Adequate project pre-development for site-specific auctions includes identifying potential substations with available capacities and suitable land for the project. It also includes securing road and evacuation line rights of way. Some of the challenges in Bangladesh's wind auction were accessing construction equipment and servicing at a remote project site and insufficient information about available capacity at the substation. A data room for bidders could deliver information on the project site's geotechnical characteristics (to assess the required site preparation work), grid connection, and RE resource estimates. Providing this information allows bidders to check their financial and technical assumptions for the project and better calculate costs.

Where it is not possible to identify suitable sites close to substations with available capacities and land, it might be necessary to expand the grid and build substations close to available sites, according to local stakeholders consulted. When constructing substations, it is important to consider flexibility for future RE capacity additions around the substation.

Should the government decide to implement site-agnostic auctions due to limited financial and human resources available to select and pre-develop sites, **capacity quotas** are an option to steer RE project development toward specific locations. The first step is to identify substations with available capacity (or where minimal upgrades would be needed)

90 While the scope of the project pre-development stage varies across countries, in this white paper it refers to planning and permitting activities implemented before the auction date.

and analyze the current and future hosting capacity of the transmission grid. Next, the government must assess land availability, the cost of land in the districts near the substation, and the RE resource potential around the substation.[91] Power demand forecasts in the surrounding region are also needed to anticipate future system needs. This information should be made available by the respective authorities in Bangladesh.

4.2.3 Physical hybrids

The feasibility of implementing physical hybrids in Bangladesh depends considerably on RE resource availability and adequate project pre-development to ensure their commercial viability.[92] Because the best wind resources are mostly limited to the coastal areas in the south and southeast, the government could prioritize identifying sites with sufficient wind resources, followed by sites rich in solar resources and with sufficient land availability.

Assuming there are sites with good solar and wind resources in certain regions, the next step is to assess potential sites in terms of the uniformity of terrain, right of way, and land ownership. Additional considerations such as flooding risks, soil erosion and frequency of natural disasters should also inform the site assessment. Moreover, the assessment should consider technical plant design challenges of solar-wind hybrids, such as potential turbine shadows on solar PV panels that would impede performance.[93] Procurement and grid planning should be well coordinated, since good solar-wind hybrid sites may be located far away from the existing grid.

According to Bangladesh's regulatory framework, RE producers are responsible for bearing grid connection costs, which makes physical hybrids more feasible.[94] Local stakeholders note that the potentially higher generation costs of physical hybrids might make the GoB less willing to promote them. However, grid connection cost savings from higher use of common grid infrastructure, compared to wind-only or solar PV-only installations, can increase physical hybrids' overall cost competitiveness.

4.2.4 Virtual hybrids

A country's regulatory framework influences the feasibility of three methods of implementing virtual hybrids: virtual hybrids participating in wholesale markets, supplying large consumers (corporate PPAs), and/or compensating providers for firm power and ancillary services.[95] Clear price signals from day-ahead and intraday markets guide aggregators' operations. Virtual hybrids can boost revenues by ramping up generation when prices in the day-ahead market are high and ramping down when prices are low. The virtual hybrid can compensate for deviations from forecasted electricity volumes through intraday trading by selling supply surpluses or buying shortages. However, there is no wholesale power market in Bangladesh, and although power trading by private actors is allowed, it is limited to trading with the state-owned utility. Larger consumers can be allowed to contract supply from virtual hybrids through corporate PPAs, but this market does not exist in Bangladesh either.

The feasibility of virtual hybrids also depends on whether the supply of firm power and ancillary services is compensated or not. "Compensation" may include either positive payments or penalties; for example, the regulatory framework might define penalties for forecast deviations for RE producers, or the aggregator might offer forecasting and balancing services for a fee. Another compensation option is for the virtual hybrid to participate in an ancillary services market, but Bangladesh lacks this type of market. Because none of these three markets exist in Bangladesh, virtual hybrids are currently not feasible.

4.2.5 Conclusions for Bangladesh

Site-specific auctions, a type of location-based incentive already implemented in Bangladesh, could benefit considerably from adequate project site selection and pre-development by the government. This could prevent issues such as the selection of sites that are difficult to reach for construction and service, as in the past wind auction. Time-based incentives can be a viable option in Bangladesh if the state-owned utility and other relevant authorities provide and regularly update information on power system characteristics

91 World Bank, *Vietnam Solar Competitive Bidding Strategy and Framework*.
92 Note that the overlap of solar and wind resources is not relevant for solar + storage or wind + storage physical hybrids.
93 USAID, *White Paper on Design Approach for Wind-Solar Hybrids*, 2020.
94 The Implementation Agreement for the wind power project at Inani (Cox Bazar) states that the interconnection line will be implemented by the developer at its own cost. Source: Government of Bangladesh 2019.
95 IRENA, *Aggregators—Innovation Landscape Brief*.

such as current and projected load patterns. Solar-wind physical hybrid auctions could be implemented but require the identification of available sites with good wind and solar resources. Virtual hybrids are currently not feasible in Bangladesh due to the absence of a wholesale power market, a market for corporate PPAs, or a way to compensate suppliers of firm power and ancillary services.

TABLE 9: Summary of the Suitability and Applicability of Design Solutions for System-Friendly RE Procurement in Bangladesh

	TIME-BASED INCENTIVES	LOCATION-BASED INCENTIVES	PHYSICAL HYBRIDS	VIRTUAL HYBRIDS (SUPPLY-SIDE AGGREGATORS)
SUITABILITY				
Timing challenge of VRE	Incentivize the supply of power during peak demand to support supply adequacy		Extend the period during which supply can be guaranteed compared to single-technology wind or solar PV plants, and (partially) support supply adequacy	Enable the shifting of VRE power to peak demand periods to increase supply adequacy
Quality challenge of VRE	(Partially) reduce the residual load		Reduce the intermittency of generation compared to single-technology wind or solar PV plants	Provide firm electricity to reduce the need for balancing requirements
Location challenge of VRE		Reduce the pressure on grid expansion and upgrades	Maximize grid use (MWh/MW) by co-locating solar with wind capacities	
FEASIBILITY				
	Requires information on current and projected load patterns to define peak and off-peak periods	Requires adequate project site selection and pre-development by the government for site-specific auctions	Requires identification of sites with both adequate wind and solar resources and land availability	Requires wholesale power market, market for corporate PPAs and/or compensation for firm power and ancillary services (none of which are currently available in Bangladesh)

CHAPTER 5.

RECOMMENDATIONS

This white paper is intended to stimulate conversation on system-friendly RE procurement in Bangladesh and concludes with recommendations and action items for procuring entities and other relevant power sector stakeholders in Bangladesh.

5.1 Recommendation 1: Continue to improve the site selection and pre-development of site-specific auctions to address grid and land constraints (location-based incentives)

Site-specific auctions can enable faster and more system-friendly RE deployment by steering RE projects to areas with easier project development, as long as the government's site selection and pre-development are sufficient. This design solution could help address problems finding sites with available grid capacity and land.

The adequate selection and pre-development of project sites requires a coordinated approach among all involved authorities to speed up project development. It can be performed by procuring agencies such as the Bangladesh Power Development Board (BPDB) and its generation companies like the Electricity Generation Company of Bangladesh (EGCB), in coordination with the Sustainable and Renewable Energy Development Authority (SREDA) and with input from the Power Grid Company of Bangladesh (PGCB).

According to local stakeholders consulted, technical expertise related to selection and pre-development of project sites should be brought up to international standards. This includes how to conduct feasibility studies, such as grid connection concepts and cost estimation, and RE resource assessments. Capacity-building for relevant institutions and support from external technical advisors are options to address this challenge.

5.2 Recommendation 2: Consider designing tender documents with tariff adjustments or supply blocks to promote a more dispatchable RE supply (time-based incentives)

Tariff adjustments or supply blocks/obligations for specific times of the day or year could incentivize Bangladesh's producers to supply power during peak demand to support supply adequacy and, to some extent, reduce the balancing requirements from conventional generators, thus addressing VRE's timing and quality challenges.

Data required to calculate tariff adjustments or supply blocks include current and expected hourly load in the transmission grid, current and expected availability of generation capacity, and its expected daily and seasonal generation patterns. Procuring entities can use this information to define peak and off-peak periods, adjust tariffs for time of delivery, or set penalties for supply shortages in the case of supply blocks.

RE procuring agencies such as BPDB can develop tender documents in coordination with SREDA and PGCB. According to local stakeholders, the GoB should facilitate the development of guidelines for procurement agencies and NLDC on how to define peak and off-peak periods, tariff adjustments for time-of-delivery, or penalties for supply shortages if supply blocks are implemented.

5.3 **Recommendation 3:** Explore the potential to auction solar-wind hybrids

Before announcing the auctioning of solar-wind hybrid capacities, procuring entities should identify sites where good wind and solar resources overlap (e.g., in Bangladesh's south and southeastern coastal regions) based on wind speed and solar radiation data such as NREL's geospatial tool for wind or the World Bank's Solargis for solar. Because the estimated energy yield of wind projects highly depends on site-specific conditions, potential wind sites should be selected first based on more site-specific measurements. Once procurers have pre-selected potential wind sites, they should perform solar resource assessments for those sites. A preliminary analysis of solar PV availability at Chattogram shows potential complementarity between wind and solar resources at this location, but detailed resource measurements at specific sites are needed.

SREDA can develop guidance documents on how to adjust the design of site-specific auctions to procure physical hybrid capacities. Key elements for the design include defining a minimum capacity utilization factor and penalties for supply deviations, as well as adjusting the ceiling price and the project commissioning deadline. According to local stakeholder feedback, procurement and grid planning processes should be well coordinated to dynamically address potential grid upgrade requirements for suitable sites located far from the existing grid.

5.4 **Recommendation 4:** Enhance power system flexibility to support the integration of VRE

Enhancing system integration of VRE requires actions beyond competitive procurement design. Power grid expansion and reinforcement allows the transmission of VRE generation to demand centers and provides flexibility by balancing VRE generation over large distances (grid management). Power imports and exports, as well as DSM, would allow the power system to react to and shift the timing of demand. Storage solutions can provide capacity services and energy shifting to deliver electricity when it is most needed, as well as fast-response grid services.[96]

Decision-makers can take measures to enhance power system flexibility, such as defining an integrated roadmap for large-scale RE integration into the energy system in concertation with relevant stakeholders such as BPDB, SREDA, PGCB, and BERC. Developing the skills and methods required to plan and operate a power system with high shares of VRE, including how to forecast RE generation and calculate operating reserve requirements, is also critical.

96 Greening the Grid, *Energy Storage*.

CHAPTER 6.

ANNEX

6.1 Key subject matter experts interviewed

- Md. Faruque Ahmed, Project Director, BPDB
- Md. Rifat Hossain, Assistant Engineer, BPDB
- Sk. Munir Ahmed, Director (Management), Power Cell
- Md. Shahnewaz Islam, Executive Engineer, BPDB
- Mrs. Jorifa Abrar, Deputy Director, BPDB
- Mr. S.M. Zahid Hasan, Deputy Director, BPDB
- Md. Muzibur Rahman, Superintending Engineer, DPDC
- Mr. Quazi Ashiqur Rahman, Executive Engineer, DPDC
- Mr. Abdullah Al Mamun, Head of Project Development Team, Teesta Solar Limited
- Mr. Habibur Rahman Faisal, Project Construction Head, Teesta Solar Limited
- Mr. Chakma Chandan, Project Engineer, Teesta Solar Limited
- Mr. Ahmed Muntasib Chowdhury, Senior Manager, Engreen Limited
- Engr. Mukit Alam Khan, Manager, US-DK Green Energy (BD) Limited
- Engr. Md. Monwar Hasan Khan, Senior Advisor, GIZ Bangladesh
- Mr. M. F. Shadekul Islam Talukder, National Expert, GFA Consulting Group GmbH

6.2 RE capacities installed, planned and under construction in Bangladesh[97]

TECHNOLOGY	CAPACITY	OWNER	LOCATION	STATUS
Solar PV[98]	3 MW	IPP	Jamalpur District, Mymensingh Division – north Bangladesh	Commissioned
Solar PV	20 MW	IPP	Chattogram Division – southeast Bangladesh	Commissioned
Solar PV	7 MW	BPDB	Chattogram Division – southeast Bangladesh	Commissioned
Solar PV	10 MW	IPP	Chattogram Division – southeast Bangladesh	Commissioned
Wind	900 kW	BPDB	Sonagazi Upazila, Feni District, Chattogram Division – southeast Bangladesh	Commissioned

97 BPDB, Annual Report 2018-2019.
98 Note that we only consider (grid-connected) utility-scale solar for this overview.

TECHNOLOGY	CAPACITY	OWNER	LOCATION	STATUS
Wind-battery hybrid (off-grid)	1 MW	BPDB	Kutubdia Island, Chattogram Division – southeast Bangladesh	Commissioned
Solar PV	45-55 MW	IPP	Rangunia, Chattogram Division – southeast Bangladesh	Under construction
Solar PV	32 MW	IPP	Dharmapasha Upazila, Sunamganj District, Sylhet Division – northeast Bangladesh	Under construction
Solar PV	50 MW	IPP	Sutiakhali, Gouripur Upazila, Mymensingh District & Division – northeast Bangladesh	Under construction
Solar PV	200 MW	IPP	Teknaf Upazila, Cox's Bazar District, Chattogram Division – southeast Bangladesh	Under construction
Solar PV	30 MW	IPP	Gangachara Upazila, Rangpur Division – north Bangladesh	Under construction
Solar PV	200 MW	IPP	Sundarganj Upazila, Gaibandha District, Rangpur Division – north Bangladesh	Under construction
Solar PV	5 MW	IPP	Sylhet Division – northeast Bangladesh	Under construction
Solar PV	35 MW	IPP	Manikganj District, Dhaka Division – central Bangladesh	Under construction
Solar PV	100 MW	IPP	Bora Durgapur, Mongla Upazila, Bagerhat District, Khulna Division – south Bangladesh	Under construction
Solar PV	100 MW	BPDB	Sonagazi Upazila, Feni District, Chattogram Division – southeast Bangladesh	Under planning
Solar PV	50 MW	BPDB	Gangachara Upazila, Rangpur Division – north Bangladesh	Under planning
Floating solar PV	Unspecified	BPDB	Kaptai Lake, Rangamati District & Mahamaya Lake, Mirsharai Upazila, Chattogram District, Chattogram Division – southeast Bangladesh	Under planning
Solar PV	50 MW	IPP	Near Bariahaat – south Bangladesh	Under planning
Solar PV	50 MW	IPP	Near Chuadanga District, Khulna Division – west Bangladesh	Under planning
Solar PV	50 MW	IPP	Near Netrokona District, Mymensing Division – northeast Bangladesh	Under planning
Wind	2 MW	BPDB	Sirajganj District, Rajshahi Division – central Bangladesh	Under planning

TECHNOLOGY	CAPACITY	OWNER	LOCATION	STATUS
Wind	30 MW	IPP	Sonagazi Upazila, Feni District, Chattogram Division – southeast Bangladesh	Under planning
Wind	Unspecified	IPP	Near to Kachua 132/33 kV Grid Substation, Chandpur District, Chattogram Division – south Bangladesh	Under planning
Wind	Unspecified	IPP	Near to Mongla 132/33 kV Grid Substation, Mongla Upazila, Bagerhat District, Khulna Division – south Bangladesh	Under planning
Wind	Unspecified	IPP	Near to Gollamari 132/33 kV Grid Substation, Gollamari, Khulna Division – south Bangladesh	Under planning
Wind	Unspecified	IPP	Near to Inani, Cox's Bazar District, Chattogram Division –southeast Bangladesh	Under planning

References

ACERA. "Resultados del Proceso de Licitación 2017/01." Santiago, Chile: Asociación Chilena de Energías Renovelables y Almacenamianto (ACERA), 2018.

Ahsan, M. "Govt to form Independent System Operator," *New Age Bangladesh*, January 31, 2018, http://www.newagebd.net/article/33786/govt-to-form-independent-system-operator.

Bangladesh Power Development Board (BPDB). BPDB Annual Report 2009-2010. Dhaka, Bangladesh: BPDB, 2010.

Bangladesh Power Development Board (BPDB). *"BPDB Annual Report 2018-19."* Dhaka, Bangladesh: BPDB, 2019a.

Bangladesh Power Development Board (BPDB), "Notice for the issuance of bid documents for selection of the project sponsors for implementation of grid-connected wind power projects having 150 capacity in aggregate each of 50 capacity on a build, own and operate (BOO) basis at three (3) sites in Bangladesh." Dhaka, Bangladesh: BPDB, 2019b, https://bd.bpdb.gov.bd/bpdb_new/index.php/site/page/e675-e19f-ceab-cdca-4de1-d0e1-4bf9-e101-543d-f168.

Bangladesh Power Development Board (BPDB), "Notice for the issuance of bid documents for selection of the project sponsors for implementation of grid-connected wind power projects having 100 capacity in aggregate each of 50 capacity on a build, own and operate (BOO) basis at two (2) sites in Bangladesh" Dhaka, Bangladesh: BPDB, 2020, https://bd.bpdb.gov.bd/bpdb_new/index.php/site/page/9c33-9b1b-5624-2f58-a4d3-9e86-74f5-68ce-6f65-fcb2.

Bankuti, M., D. Chattopadhyay, and C. Song. "Integrating Variable Renewable Energy in the Bangladesh Power System: A Planning Analysis." Washington, D.C., USA: World Bank, 2018.

Bellini, E. "Qatar's 800 MW tender draws world record solar power price of $0.01567/kWh," *PV-Magazine*, January 23, 2020, https://www.pv-magazine.com/2020/01/23/qatars-800-mw-pv-tender-saw-world-record-final-price-0-01567-kwh/.

BERC. "Electricity Grid Code 2018." Dhaka, Bangladesh: Bangladesh Energy Regulatory Commission, 2018.

Chandrasekaran, K. "Tariffs remained unchanged in hybrid auction," *India Times*, May 28, 2019, https://economictimes.indiatimes.com/industry/energy/power/adani-green-energy-renew-power-only-bidders-in-hybrid-auction/articleshow/69420860.cms.

Chawdhury, M.A. and D. Chattopadhyay. "A New Beginning in Frequency Control for the Bangladesh Power System." Presented at IEEE Power & Energy Society General Meeting (PESGM), Portland, OR, USA, August 5-10, 2018.

Electricity Generation Company of Bangladesh Ltd. (EGCB). "Terms of Reference (TOR) For Selection of Joint Venture (JV) Partner for Implementation of 10 MW Wind Power Plant Project at Sonagazi, Feni, Bangladesh." Dhaka, Bangladesh: EGCB, 2018.

Energinet. "Ancillary Services to be Delivered in Denmark – Tender Conditions." Fredericia, Denmark: Energinet, 2017.

"Energy Storage," Greening the Grid, https://greeningthegrid.org/Grid-Integration-Toolkit/Topics-And-Resources/energy-storage/energy-storage.

"GDP growth (annual %) – Bangladesh," World Bank, https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=BD.

"Glossary – Auction," Auctions for Renewable Energy Support (AURES), http://auresproject.eu/auction.

"Glossary," Greening the Grid, https://greeningthegrid.org/about/glossary/glossary.

Government of Bangladesh. "Power System Master Plan (PSMP) 2016." Dhaka, Bangladesh: Ministry of Power, Energy and Mineral Resources, 2016.

Government of Bangladesh. "Revisiting Power System Master Plan (PSMP) 2016." Dhaka, Bangladesh: Ministry of Power, Energy and Mineral Resources, 2018.

Government of Bangladesh. "Implementation Agreement by and between the Government of the People's Republic of Bangladesh and Power Grid company of Bangladesh and [Name of Company]. 2019." http://bpdb.gov.bd/bpdb_new/d3pbs_uploads/files/IA%20Wind%20Turbine%2050%20MW-IPP%20-%20Inani.pdf.

Government of Chile. "Resolución Exenta N°438 Modifica Bases de Licitación 2017-01." Santiago, Chile: Comisión Nacional de Energía, 2017.

Government of Chile. "Energy Statistical Yearbook 2017." Santiago, Chile: Ministry of Energy, 2018.

Government of India, Ministry of New and Renewable Energy, https://www.india.gov.in/website-ministry-new-and-renewable-energy.

Guidehouse Insights (formerly Navigant Research). "Navigant Research Leaderboard: VPP Platform Providers. Assessment of Strategy and Execution for 15 Companies Leaderboard: VPP Platform Providers." Navigant Research, 2010.

Hasan, S. "COVID-19 fallout: Power transmission projects work to be delayed by a year," UNB, June 5, 2020, https://unb.com.bd/category/special/covid-19-fallout-power-transmission-projects-work-to-be-delayed-by-a-year/52568

International Energy Agency (IEA). "System Integration of Renewables." Paris, France: IEA, 2018.

International Energy Agency (IEA). "Global Energy Review 2020." Paris, France: IEA, 2020.

International Renewable Energy Agency (IRENA). "Aggregators: Innovation Landscape Brief." Abu Dhabi, UAE: IRENA, 2019.

International Renewable Energy Agency (IRENA). "Renewable Energy Auctions: A Guide to Design." Abu Dhabi, UAE: IRENA, 2015.

International Renewable Energy Agency (IRENA). "Renewable Energy Auctions: Status and Trends Beyond Price." Abu Dhabi, UAE: IRENA, 2019.

Klinge, S. "Wind power and ancillary services in Denmark – Experiences from a power system without must-run obligations." Presented at WindEurope 2018 Conference, Hamburg, Germany, September 2018.

Next Kraftwerke, "Presentation at Bürgerdialog Stromnetz," Berlin, Germany, 2016.

Nikolakakis, T., D. Chattopadhyay, and M. Bazilian. "A review of renewable investment and power system operational issues in Bangladesh." Renewable and Sustainable Energy Reviews, 68 (2017), 650-658.

NREL, "Wind and solar on the power grid: Myths and misperceptions," Greening the Grid, https://www.nrel.gov/docs/fy15osti/63045.pdf, 2015.

"Overview of Grid Integration Issues," Greening the Grid, https://greeningthegrid.org/Grid-Integration-Toolkit/quick-reads.

Ovi, I.H., "IMF: Bangladesh to overtake India in per capita GPD," Dhaka Tribune, October 13, 2020, https://www.dhakatribune.com/business/economy/2020/10/13/imf-bangladesh-s-gdp-to-grow-3-4-in-2020.

Palchak, D., J. Cochran, A. Ehlen, B. McBennett, M. Milligan, and I. Chernyakhovskiy, "Greening the Grid: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid, Vol. I—National Study." Washington, D.C., USA: National Renewable Energy Laboratory (NREL), 2017.

Pargal, S. "Lighting the Way: Achievements, Opportunities, and Challenges in Bangladesh's Power Sector." Washington, D.C., USA: World Bank, 2017.

Parikh, A. "Greenko, ReNew Win SECI's 1.2 GW Solar, Wind Auction with Storage for Peak Power Supply," *Mercom India*, January 31, 2020, https://mercomindia.com/greenko-renew-win-seci-solar-wind-auction-with-storage/.

Prateek, S. "India's First Mega Solar-Wind Hybrid Auction Sees Lowest Tariff of ₹2.67/kWh," *Mercom India*, December 5, 2018, https://mercomindia.com/seci-solar-wind-hybrid-auction-results/.

Prateek, S. "₹2.51/kWh Wins SECI 2 GW ISTS Wind Auction," *Mercom India*, April 6, 2018, https://mercomindia.com/seci-2gw-wind-auction/.

Prateek, S. "Mahindra Susten Emerges as Lowest Bidder in NLC India's 20 MW Solar with BESS Auction," *Mercom India*, April 16, 2018, https://mercomindia.com/mahindra-l1-bidder-20mw-bess-nlc-auction/.

Prateek, S. "SECI's 750 MW Solar Auction for Rajasthan Sees Lowest Tariff of ₹2.50/kWh," *Mercom India*, June 19, 2019. https://mercomindia.com/seci-750-solar-auction-rajasthan/.

"Products - Power producers," Next Kraftwerke, https://www.next-kraftwerke.de/virtuelles-kraftwerk/stromproduzenten.

Rijal, P. "Nepal likely to export power to Bangladesh using Indian grid," *Kathmandu Post*, October 17, 2019, https://kathmandupost.com/money/2019/10/16/nepal-likely-to-export-power-to-bangladesh-using-indian-grid.

Salgado, A., M. Taylor, and F. Boshell, "Wind farms for cyclone zones: new standards and designs," *Energy Post*, October 9, 2019, https://energypost.eu/wind-farms-for-cyclone-zones-new-standards-and-designs/.

Solar Energy Corporation of India Limited (SECI). "Request for Selection (RfS) Document for setting up of 2500 MW ISTS-connected Wind-Solar Hybrid Power Projects (Tranche-I)." New Delhi, India: SECI, 2018.

Solar Energy Corporation of India Limited (SECI). Request for Selection (RfS) Document for Selection of Project Developers for setting up of 1200 MW ISTS-Connected RE Projects with assured Peak Power Supply in India (ISTS-VII). New Delhi, India: SECI, 2019.

Sustainable and Renewable Energy Development Authority (SREDA). "National Database of Renewable Energy." Dhaka, Bangladesh: SREDA, 2020.

Trabish, H. "Utilities take note: Hybrid renewables projects are coming," *Utility Dive*, April 3, 2018, https://www.utilitydive.com/news/utilities-take-note-hybrid-renewables-projects-are-coming/520319/.

United States Agency for International Development (USAID). "Challenges in the Development of Variable Renewable Energy in Bangladesh." Washington, D.C., USA: USAID, 2020.

United States Agency for International Development (USAID)and Kazakhstan Electricity and Power Market Operator (KOREM). "Renewable Energy Auctions in Kazakhstan: 2018-2019 Results." Washington, D.C., USA: USAID, 2020.

World Bank. "Combined Project Information Documents / Integrated Safeguards Datasheet (PID/ISDS)." Washington, D.C., USA: World Bank, 2018.

World Bank. "Vietnam Solar Competitive Bidding Strategy and Framework." Washington, D.C., USA: World Bank, 2019.

SCALING UP RENEWABLE ENERGY (SURE)

USAID FROM THE AMERICAN PEOPLE

FOR MORE INFORMATION

Shayan Shafi
Senior Energy Advisor
USAID Bangladesh, Dhaka
SShafi@usaid.gov

Ritesh Kumar Singh
SURE/Bangladesh Activity Lead
Tetra Tech (SURE Implementing Partner)
RiteshKumar.Singh@tetratech.com